THE

ECOLOGY AND CONTROL

OF THE

FOREST INSECTS

OF

INDIA

AND THE NEIGHBOURING COUNTRIES

By

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+ To my Father +

and in Memory

+ of my Mother +

AUTHOR'S PREFACE

"Writing books seems inevitable somehow;
but publishing them is an indulgence"

(T. E. Shaw to G. B. Shaw, Karachi, 1928)

WHEN planning this book I was greatly helped by the official opinions of Forest Departments and many individual suggestions. They covered a wide range of needs and specified at least a manual of pests and control methods for the divisional officer and his staff, a textbook for lecturers and students at the Forest Colleges, as well as a work of reference for research officers and entomologists; moreover the book should be cheap and portable. The specification resembled that for a radio set built to give perfect reception of the local station and yet to get everything everywhere: simple enough to be operated by a novice and yet with that flexible complexity which responds miraculously to the touch of an expert.

In deciding how to meet these divergent demands the utility of separate guides to the insects of each forest division or of each species of tree was considered, and forest departments selected over 50 species of trees for treatment on these lines. One sample guide (for *Dalbergia sissoo*) was enough to show that such a series, even with the most concise arrangement of subject-matter, would be more voluminous and more expensive than a single encyclopaedic book from which exactly the same information could be extracted as needed.

Educational demands were examined and met by providing a supplementary textbook on forest zoology that excludes the ecology and control of insects.

The residual subject-matter incorporated in this book may seem formidable but it is elaborated with page-headings, paragraphs, cross references and synopses so that the forester may pick out his special items with certainty and ease; from any spot on which he parachutes he should readily reach his objective.

To reduce the retail price of the book I have dispensed with a publisher and printed it locally on a small platen-press, a form at a time — an unconventional method made possible by the craftsmanship of the Vasant Press which has successfully overcome the limitations of the machine and type at its disposal; for the typographical errors author and printer are jointly responsible.

Costs have been reduced also by borrowing blocks for illustrations. It is hoped that the text does not appear to have been indiscriminately bombed with figures and plates; they were aimed methodically at insect friends as well as foes. Acknowledgements are gratefully made to the Imperial Agricultural Research Institute for the loan of blocks for figures 33, 34, 38, 63, 71, 72,

77–82, 85, 89, 91, 93, 94, 102, 103, 105, 122, 126, 132, 134, 160, 161, 164, 165, 172–174, 177–179, 183–185; and to the Imperial Council of Agricultural Research for figures 127, 128, 139, 141–145, 148, 158, 159, 166, 168, 169, 180; and to the Malarial Bureau for figures 123, 124; and to the Indian Forester for figure 150; and to the Forest Research Institute for the remainder. Several blocks were specially prepared for the book.

I am also indebted to Mr. Gardner and the assistants in the Entomological Branch for criticisms and corrections and for help in reading proofs.

New Forest C. F. C. BEESON

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HOW TO USE THIS BOOK

Some hints for Forest Officers

To find out what control measures are prescribed or suggested for a particular kind of damage to a forest tree or its timber one must start with either (a) the name of the insect, or (b) the ecological group of insects likely to have caused the damage, or (c) the name of the tree.

The arrangement of the 4,300 species of insects mentioned in the book is not systematic or phylogenetic but alphabetical on the basis of Order, Family, Genus and Species. The pages of Part One (Ecology) and Part Two (Control) are index-headed with the name of the family and of the order, both abbreviated. The abbreviations for the names of the orders are Anoplura ANO, Coleoptera COL, Collembola COLLEM, Dermaptera DER, Diptera DIP, Ephemeroptera EPH, Hymenoptera HYM, Isoptera ISO, Lepidoptera LEP, Mallophaga MAL, Neuroptera NEUR, Odonata ODO, Orthoptera ORTH, Rhynchota RHYN, Siphonaptera SIPH, Thysanoptera THY, Thysanura THYSANURA. The abreviation for the name of the family is obtained by omitting the termination IDAE, thus: Apidae AP, Geometridae GEOMETR, Hyblaeidae HYBLAE, Simuliidae SIMULI.

If the name of the insect is known proceed as follows:—

(a)—Turn up (i) the index at the end of the book or (ii) the page-headings alphabetically, first by order, then family, then genus and finally species in Part One for life-history and economic importance, and similarly in Part Two for control measures. If the family or order is not remembered, the index must be consulted for the page-reference to the genus. Read all the cross-references quoted under a species.

If the name of the insect is not known proceed as follows:—

(b)—Taking the type of damage as a basis turn up the synopsis on pp. 22, which gives the names of the families most likely to be concerned; having selected a family turn it up by the page-headings in Part One and read the introduction to the family, finally read the accounts of the genera suspected (see also p. 876). If convinced that the author of the damage has been indentified turn up the family page headings in Part Two.

(c)—Taking the name of the tree as a basis turn it up in the general index; the page-references refer to a few of the most commonly encountered pests of the living tree. Use these references in conjunction with the information obtained from the preceding method.

These short-cuts are unsatisfactory and unreliable substitutes for the correct identification of the insect but may by chance lead the enquirer to the commonest species of pests.

No control operations should be undertaken unless and until an authoritative identification has been obtained that a species of

pest does occur in the division and does attack the species of tree in question. Read pp. 867–876.

Instructions for collecting, preserving and packing insects and examples of insect damage are given on pages 988–990.

Those who wish to take up insect-collecting as a hobby should refer to the general account of the family or order chosen and consult the references to LITERATURE. Any monograph or catalogue or comprehensive article which has been published in the *Fauna of British India* or in departmental and society's journals, memoirs, records, bulletins, etc., in India, Burma and Ceylon is referenced, but other publications which are only obtainable in second-hand bookshops or in foreign scientific journals are not mentioned as they are practically inaccessible to the beginner. Further advice and help will be given by the Forest Research Institute.

ERRATA

p. 40 l. 9, und not aud; p. 47 l. 14, *Stephegyne* not *Stephygyne*; p. 47 l. 17, *tumbuggaia* not *tumbuggiana*—l. 30, *Millettia* not *Milletia*—l. 31, *cordatus* not *cordata* –last line, *Girardinia* not *Gerardinia*; p. 48 l. 32, *longepetiolatum* not *longipetiolatum*; p. 57 l. 16, then not than; p. 68 fig. 14, No. 3, *Heterobostrychus* not *Heterobstrychus*; p. 81 l. 25, *Millettia* not *Milltetia*; p. 83 l. 33, *Heritiera* not *Hertiera*; p. 85 l. 43, *xylopyrus* not *xylopyra*; p. 90 l. 45, ditto; p. 95 l. 33, ditto; p. 98 l. 11, myrmecophilus not mymecophilus –l. 24, insert or between more less –l. 33, Aggressors not Agrossors; p. 102 l. 1, aggressive not agressive; p. 104 fig. 30, *Jonthocerus* not *Jonthoceras*; p. 110 l. 7, *Ipomaea* not *Ipomoea*; p. 117 l. 2 and 11, *Chickrassia* not *Chikrassia*—l. 33, *Holoptelea* not *Holoptelia*; p. 128 l. 25, delete from; p. 130 l. 10, dumbbell not dumbell; p. 136 last line., mature not matnre; p. 145 l. 11, *Mitragyna* not *Mitragyne*; p. 155 l. 28, Chloridolum not Chloridolium p. 156 l. 42, *Mitragyna* not *Mitragyne*; p. 157 l. 26, *fraxinifolius* not *fraxinifolia*; p. 158 l. 6, ditto; p. 160 l. 28, *Mallotus* not *Mallotns*; p. 164 l. 41, tunnelling not tunelling; p. 177 l. 33, the not tho; p. 188 fig. 60, Nothorhina not Nothorrina; p. 202 l. 17, *Millettia* not *Milletia*; p. 212 l. 29, *Litsaea* not *Litsea*; p. 218 last line., insert "is" between species and notable; p. 221 l. 11, *Poinciana* not *Poinciania*; 221 l. 18, *Ipomaea* not *Ipomoea*; p. 237 l. 44, Pseudoclerops not Psuedoclerops; p. 248 l. 34, Pseudobothrideres not Pseudobothrides; p. 253 l. 40, Indian not India; p. 258 l. 2, Anius not Anisus; p. 261 l. 23, *Morus* not *Mo us*- –last line *glomerata* not *glomeratus*; p. 266 fig. 83, No. 69, Anius not Anisus; p. 279 l. 2, *neriifolium* not *nerifolium* –l. 5, *Litsaea* not *Litsea*; p. 291 l. 28, *roxburghianus* not *roxburgianus*; p. 316, The true Cantharidae are not described in this book; p. 317 l. 23, Cantharis rouxi and C. tenuicollis should be classed in *Decapotoma* or *Psalydolytta*

not *Cantharis* of modern authors; p. 329 l. 32, *semecarpifolia* not *semicarpifolia*; p. 336, fig. 100, l. 2, *robusta* not *rebusta*; p. 373 l. 24, *Excaecaria* not *Exaecaria*; p. 390 l. 19, *ferrea* not *ferra*; p. 394 l. 11, *Excaecaria* not *Exaecaria* -l. 12, *littoralis* not *litoralis*; p. 402 l. 11, *acuminata* not *acuminatus*; p. 455 lower figure, the hind legs do not show the essential characters of *Sturmia*; p. 488 heading, CHALCID not CAHLCID; p. 505 last para, for **C.** read **Calliephialtes**; p. 641 l. 20, **Stilpnotia** not **Stilponita**; p. 647 l. 44, **Diphthera** not **Dipthera**; p. 670 l. 1 delete **Bombotelia jocosatrix,** see p. 647; p. 705 heading, TORTR not THYRID; p. 737 l. 44, **Cosmoscarta** not **Cosmocarta**; p. 777 fig. 194, note that the number 194 is duplicated on p. 791; p. 781 l. 34, close bracket; p. 789 l. 10, after wingless insert "or have rudimentary wings"; p. 791 fig. 194, note that the number 194 is duplicated on p. 777; p. 715 l. 24, for in face of read "apart from": **biotic potential** is a definite characteristic of a species independent of environmental resistance; p. 796 l. 11, see p. 24 for the meaning of life-cycle; p. 802 l. 32, after bores insert "as well as its water of metabolism"; p. 812 l. 18, available not avilable; p. 814 l. 10, polyphagous not polyghagous; p. 820 l. 12, for suicidal read "internecine"; p. 825 l. 37, insert "bird" after enthusiastic; p. 818 l. 21, for "of" read "to"; p. 872 l. 11, compel not compell; p. 873 l. 4, for "entirely dependent on dead wood" read "flourishes where shelter-tunnels are easily made"; p. 879 l. 46, teacupful not teacupfull; p. 893 l. 12, delete hyphen after Panels; p. 933 l. 19, insert "in wood" at beginning of line; p. 936 l. 5, delete comma after floor; p. 957 l. 31, insert "e.g.," before *Phanerotoma*; p. 961 fig. 203, the arrow joining predators and parasites of puera is superfluous.

P. 776 Description of Fig 193 should read:

Oxyrachis tarandus, Nos. 1, 2, 3, egg slits in twig of *Albizzia lebbek* and egg enlarged. Nos. 4-9, details of head and abdomen (genitalia) of adult.

HISTORY OF FOREST ENTOMOLOGY IN THE INDIAN REGION

IT was not until after the middle of the eighteenth century and the Linnean period, when the early Christian missions and the Honourable East India Company made their influence felt, that serious regular scientific work began on Indian insects. J. G. Koenig had published the first life-history of an Indian termite (1779), and J. Kerr had described and named the already well known lac insect (1781), when the Asiatic Society of Bengal was inaugurated in 1785. The establishment of this society afforded further stimulus and approval for the activities of the pioneers in natural history. Those who are interested in ancient insect lore and the modern development of Indian entomology should read the Presidential Address of M. Afzal Husain at the twenty fifth Indian Science Congress, 1938, *Entomology in India: Past, Present and Future*, and T. V. Ramakrishna Ayyar's *Entomology in India—A Retrospect* (1939).

Early records of forest insects

For the earliest references to forest insect pests that can be identified specifically one must turn to the reports of the scientific officers who explored the forest resources of Tenasserim, Burma, in the second quarter of the 19th century. Dr. J. W. Helfer (1810–1840) seems to have been the first to collect insects because they were pests of trees. He observed in 1836 that many trees were girdled and left unfelled.

"The number of killed trees which are suffered to decay generate a host of insects. Though it is pretended that teak is not attacked by vermin, yet a great deal of these decayed trees are attacked by Bostrichus, Passalus and other coleopterous insects and the consequence is that these animals have attacked other good trees before they were sufficiently seasoned."

Helfer might have done much for forest entomology but for his untimely death in 1840. The first records of the Beehole Borer of Teak, *Xyleutes ceramica* Wlk. (Cossidae) are to be found in the reports of Captain Tremenheere (1841) and Captain Guthrie (1845). Dr. Falconer noted in 1851 that Malabar teak is free from the "holes and clefts" which occur in Tenasserim teak. Early data on the food-plants and larvae of forest insects are assembled in Horsfield and Moore's Catalogue printed in 1857/9; numerous illustrations of larvae are given in hand coloured plates. A few observations on borers of timbers in south India were made by

Note: This detailed history of forest entomology in the Indian Region has been prepared to amplify and in part to correct earlier shorter accounts.

L. O. Howard, 1930, History of Applied Entomology, *Smiths. Misc. Coll.*, Vol. 84.

H. S. Rao, 1938, Zoology, Progress of Science in India during the past 25 years.

B. Prashad, 1939, Über die angewandte Entomologie in den verschiedenen Ländern, 10. Applied Entomology in India. *Arb. phys. angew. Ent.*, Berlin-Dahlem, 6, pp. 66–72.

Dr. H. Cleghorn and S. N. Ward, C. S., between 1858 and 1860 (Cleghorn, 1861).

Col. Ramsey, Commissioner of Kumaon, U. P., had observed about 1865 that sal, if girdled, is attacked by borers that ruin the timber. R. Thompson, Assistant Conservator, was directed to investigate timber borers and worked in the forests of Garhwal and Kumaon in 1866–7. His "*Report on Insects Destructive to Woods and Forests*" was published in 1868; it is not only the first publication devoted to Indian forest insects but is remarkable for its illustrations which consist of crude engravings and direct photographic prints—the latter are today clear enough for accurate identification of the beetles illustrated.

In July 1875, the service journal, *The Indian Forester*, appeared and became a medium for the publication of notes on damage by insects. An account of the Toon Shoot-borer may be found in the first volume; this insect, *Hypsipyla robusta* Moore (Pyralidae), was not named and described till 1886. In that year the *Journal* of the *Bombay Natural History Society* started publication.

Early educational hand-books on forest insects

For the use of students at the Imperial Forest School at Dehra Dun, the first text-book was issued in 1888 by M. H. Clifford, Assistant Conservator (I. F. S., 1881–1890). Insects were dealt with in very general terms, no species being mentioned; nevertheless various remedial measures were prescribed. In 1875 the Indian Museum, Calcutta, was founded and since about 1888 had become a centre of information on injurious insects. In 1891, E. C. Cotes, who had been Deputy Superintendent since 1884, prepared a memorandum for 'An Elementary Manual of Zoology' which was published in 1893. This author was able to quote specifically only a few forest pests and, for his biological data, had to rely in the main on foreign examples or agricultural insects. From this period onwards interest in forest insects increased and specimens were sent for identification to the Indian Museum; records were published in *Indian Museum Notes*. About this time the *Fauna of British India* series was initiated and the first volume on insects, Hampson's *Moths*, appeared in 1893.

All the information available upto 1898 was compiled by E. P. Stebbing (I. F. S., 1893–1914) in a pamphlet entitled *Injurious Insects of Indian Forests* (1899); this included about 100 named species for which 74 text-figures and 9 photo-etched plates were provided. Among the forest officers who collected insects in the last half of the 19th century were H. L. Andrewes (I. F. S., 1885–1888), T. R. D. Bell (I. F. S., 1884–1920) famous for his studies on butterflies and a *Fauna* volume on hawk-moths, C. T. Bingham who produced *Fauna* volumes on ants, bees, wasps and butterflies, Craddock, F. Gledhow (I. F. S., 1879–1911), T. A. Hauxwell (I. F. S., 1880–1915), C. G. Rogers (I. F. S., 1887–

1920), A. Smythies (I. F. S., 1873-1902) and R. C. Wroughton (I. F. S., 1871-1904).

Appointment of a forest entomologist

To B. Ribbentrop, Inspector General of Forests, is due the credit of demonstrating the need for a forest entomologist and, incidentally, in making it the first research post to be held by a forest officer in India. As he states in *Forestry of British India* (1900), "We have had already indications that insects may do widespread damage to our Indian forests, and as, under our present management, the intermixture of our most valuable trees becomes more and more pronounced, and in many instances will lead us to the establishment of large areas of more or less pure forests, this danger from insects may, and probably will, become more intense in the future. For this we should become fully prepared and armed". The advanced development of the science of forest entomology in Europe at the close of the nineteenth century apply justified Ribbentrop's conviction that it was time to make a beginning in India.

The post was sanctioned for two years and Stebbing was apointed at the end of 1900. "It was the foundation-stone on which a great edifice was to arise in the course of the next two decades" says Stebbing in his *Forests of India* (1923, II, p. 611), —but, as it happened, not without a temporary rejection by the architects.

". . . At the end of my first year's work as Forest Entomologist, I was in Calcutta and the Inspector General of Forests [H. C. Hill] sent for me. My appointment had been sanctioned by the Government of India at the instance of his predecessor and he himself was not a great believer in the possibilities of entomological research in connection with forests. 'Look here, Stebbing' was his greeting, 'you have had a year now. I must have some published material from you to justify this appointment.' I stood tongue-tied before him". . . (1939, p. 7).

Stebbing's ever-prolific pen quickly replied to this demand; in 1901 another *Syllabus of Zoology Lectures* for students at the Imperial Forest School was published, and in (1902 *Departmental Notes on Insects that affect Forestry* began to appear and continued till 1906. He also started popular articles on insect life in the *Indian Forester* and the *Journal of the Bombay Natural History Society* which ran in serial parts from 1901 to 1908. But in spite of the efforts of R. C. Wroughton, Inspector General, to obtain the prolongation of the post it was dropped for the time being and Stebbing took the officiating post of the Superintendent of the Indian Museum early in 1903.

Foundation of the Forest Research Institute

As a result of the representation of Sir S. Eardley Wilmot, Inspector General, the Imperial Forest Research Institute was established in 1906 by raising the status of the Forest School at Dehra Dun and creating six research posts, 5 filled by forest service officers. Stebbing was appointed Imperial Forest Zoologist in April 1906, and held the office until December 1909. (The post was renamed Forest Entomologist in 1922).

Before 1904 accomodation for the Entomologist had been provided in the Forest College and in a house in Dehra Dun, but

thereafter a separate building at Chandbagh was used, the zoological exhibits being displayed in the College Museum. This bungalow in the Chandbagh estate served for the office, laboratory and insectary of the Forest Zoologist until 1914 when the Research Institute new buildings were completed. Soon after the inaguration of the Institute, series of *Memoirs*, *Records*, *Bulletins*, *Pamphlets* and *Leaflets* were created for the publication of the results of research. It is unnecessary to detail here the items dealing with forest insects; all are quoted in the parts of this book dealing with Ecology and Control. Stebbing contributed abundantly to each series and in 1907 completed *A Manual of Elementary Forest Zoology for India*. He left India in December 1909 and after his departure published in 1914 *Indian Forest Insects of Economic Importance—Coleoptera*, a book with 648 pages, 401 textfigures and 64 plates—the most sumptuous work ever produced on Indian forest beetles or likely to be. In December 1909 V. Subramaniya Iyer (P. F. S., 1899-1913) was appointed Temporary Forest Zoologist and held the post till April 1911. S. Maulik was his assistant in 1910 and 1911 (later the author of volumes in the *Fauna of British India* on Chrysomelidae). In October 1911, A. D. Imms, Professor of Biology at Allahabad University was appointed with one assistant, N. C. Chatterjee (1911 to date). During his sixteen months' tenure of office he introduced valuable reforms; extensive additions were made to the library; contacts were made with entomological specialists in many countries and large collections were distributed to them. He designed an insectary and laboratories which were erected according to his plans after his departure. Dr. Imms' association with forest entomology at a time when a new Institute was projected and funds for expansion of entomological research had to be secured, was a most fortunate occurrence.

In August 1913, C. F. C. Beeson (I. F. S., 1911 to date), who had studied entomology during the first year of his service under H. M. Lefroy in London and K. Escherich in Tharandt, was transferred from the Punjab to take over the post of forest Zoologist. Stebbing makes a pertinent comment on this appointment in *Forests of India*, III, p. 386, 1926. The accomodation in the new Forest Research Institute at Chandbagh was occupied in 1914 and served its purpose throughout the War years, but by 1919 the Government of India was already considering schemes for further expansion.

Development of ecological research on Indian forest insects

In its early phases Indian forest entomology was strongly influenced by European textbooks of forest protection in which the insect pest is presented as an entity apart from the tree,—as a specific disease of cultivation, a disease of which the etiology is known, and for which the clinical symptoms have been defined and the remedies prescribed. By 1900 there were no less than 19 textbooks

available on forest insects. This simplified conception undoubtedly fostered the idea that forest entomology in India comprises problems of a similar nature, and that the control of an insect pest can be obtained by a simple investigation of its life-history or the discovery of a weak link in the chain of its metamorphoses. Hence, the demand from the Forest Department was for remedies that should be at once cheap, simple and interfere in no way with the customary silviculture and management. There had been no catastrophic epidemics wiping out large areas of forest. There was an almost complete ignorance of the financial aspect of depreciation and loss of increment due to annual attacks, and no system by which it could be assessed and regularly recorded. Interest was centered mainly on the evident damage that occurred to intensive cultivation, e.g., in nurseries, taungyas, plantations and natural regeneration areas of the uniform systems. To such conditions the principles of agricultural pest control are, as in European forestry, almost directly applicable and the problem is one of costs rather than of methods. The position at this period can be summed up in the forester's standard criticism—"These remedies are feasible for a few acres but are impracticable on a large scale".

In 1916 the Board of Forestry expressed its opinion that "insufficient attention is paid (by the Forest Department) to the introduction of control measures for insect pests", and considered that "control measures to be of any use must be carried out continuously on a large scale and must be of a preventive rather than a remedial nature. As the necessary staff for such operations does not at present exist, . . . progress must depend largely, if not entirely, on the appointment of provincial research officers working in connection with, and with assistance from, the Zoologist. . . The staff of the Zoologist should be increased by the appointment of field assistants who would be employed in investigational work where prolonged local study is required and who would initiate and carry out control measures".

Two assistants S. N. Chatterjee (1917 to date) and B. M. Bhatia (1918 to date) were added to the Zoologist's staff. Very little was done in the Provinces to record the incidence of pests or to introduce regular control measures.

It was thus becoming evident that the most profitable lines of research in tropical and subtropical forest entomology were those in which the study of associational ecology precedes that of individual ecology. Instead of isolating the species and viewing it as the hub of a microcosm it had to be studied as one of a group or biotic association of animals possessing the same habitat and environment. In most cases in which investigations were started with the assumption that a particular type of damage to a particular species of tree is due to a single and universal factor, the factor has resolved into many, involving not only the valuable tree it is desired to protect, but also its less valuable—and often worthless, associates. A research policy based on these principles demanded ecological surveys on broad lines and the continuity of long-period projects; there was, moreover, every hope that continuity in research would be maintained. The policy of extensive ecological surveys was accepted as essentially the

function of the central Institute, and was incorporated in proposals for expansion of the Branch of Forest Zoology[*] despatched by the Government of India to the Secretary of State in December 1919. The field of work in India and Burma was divided into four phytogeographical regions each of which was to be in charge of a Regional Zoologist (later renamed Divisional Forest Entomologist) with an assistant. The erection of a new Forest Research Institute, and increase in the research staff in all Branches was sanctioned in 1920.

Beeson was instructed, when on leave in 1920, to arrange for the recruitment of three officers to fill the new entomological posts. Dr. M. Cameron (Surgeon Commander, R. N., retired), J. C. M. Gardner (I. F. S., 1921 to date, who studied entomology under Lefroy and forestry at Cambridge), and D. J. Atkinson (I. F. S., 1921 to date, then a probationer at Oxford) accepted the appointments. Cameron arrived in India in December 1920 and his post was designated Systematic Entomologist, as it had been meanwhile decided to apply one of the posts of Divisional Forest Entomologist to systematics until such time as the full regional strength could be recruited by training men in both entomology and forestry. A second assistant entomologist, S. K. Pillai who had been trained in Germany, was appointed in December 1921.

The two Divisional Forest Entomologists were posted to Bengal and Burma as Assistant Conservators of Forests in 1921. By this time the financial situation had changed for the worse and the Indian Retrenchment Committee sat during 1922-3 and recommended a reconsideration of the whole scheme for the expansion of the Institute. Of the posts of Divisional Forest Entomologist two were placed in abeyance and one was reduced; they have remained unfilled to the present day.

After two and a quarter years' work Cameron[†] was forced to resign for reasons of health but the post of Systematic Entomologist was made permanent and Gardner was transferred from Bengal to fill it in August 1923. A third Lower Assistant, G. D. Bhasin, (1923 to date) was appointed in 1923.

The new Research Institute at New Forest provided the Entomological Branch with extensive accomodation including 160 running feet of north lighting in laboratories and a capacious Insectary (a separate building) and an experimental garden with outdoor cage units. The new quarters were occupied in 1926. The main building of the Institute was under construction for some years and was not formally opened until 1930. To the post of second Assistant Entomologist which had become vacant in 1925, R. N. Mathur (1927 to date) was appointed in 1927.

[*]This designation was changed to Forest Entomology in 1922.

[†]Cameron continued his work on Staphylinidae in England and has recently published his fourth volume on this family in the *Fauna of British India*.

Development of research by means of field-insectaries

The Board of Forestry did not meet again till 1925 when the future of the Entomological Branch came under reconsideration. It resolved that "The further expansion of the branch must be delayed until suitable financial provision is made." In addition an important principle was accepted:—"The present staff of the entomological branch cannot undertake much more detailed local work, and when any province is anxious to have an enquiry made on any special pest, that province should collect the data required by the entomologist, and arrange for the training and employment of the necessary staff, under the guidance of the Entomologist." From this principle has eventually developed a system of cooperative research financed partly by the Institute and partly by the Provincial Forest Department concerned. The necessary local data are collected in field-insectaries, staffed by the Institute and operated continuously for several months during the working season. Insectaries of this type have been used in Bengal, Bombay, the Central Provinces, Coorg, Madras, Mysore and the Punjab for the investigation of the major pests of champ, sandal, shisham and teak.

In effect, therefore, an appreciable amount of the work projected for the regions defined in 1919 has been undertaken by assistant entomologists and field-parties working in temporary insectaries.*

An outstanding example of cooperative research is the work done on the spike disease of sandal in 1930-1933, when the Governments of Coorg and Madras and the Research Institutes at Dehra Dun and Bangalore jointly contributed funds and personnel, and special staff was engaged and trained on behalf of Forest Departments. After the closing down of the scheme in September 1933 the Madras Forest Department was able to continue the investigation successfully through the agency of its own research staff.

The field-insectary method has proved a satisfactory solution for present day needs but it is not capable of unlimited expansion so long as the work of assistant entomologists in charge of insectaries requires the direct supervision of a Forest Entomologist. Its future development must involve the appointment of regional entomologists on the cadre of the central institute, or of provincial entomologists on the research staff of the provincial departments.

Biological control

In the 1938 revision of the forest department code, 7th ed., 1913, the policy of entomological research was redefined as . . . "The Entomologist is required to study systematically the effect, beneficial or otherwise, exercised by animals on the development and reproduction of Indian forests with the object of discovering the measures which can be undertaken, with the greatest prospect of success, to encourage the development of useful species and to destroy those which are injurious. The most important work of the Entomology Branch at present must be the investigation of epidemic disease and the biological control of insects and weeds"

*The independent development in Burma in described on page 14.

In the realm of biological control (which in tropical forestry is really silvicultural control designed to promote biotic control), the diverse ecological conditions on the subcontinent have been extensively sampled for several years. The survey of the distribution, food-plants, hosts, food-chains, life-cycles, etc., of forest insects that are not scheduled pests of forests has formed a background to all strictly economic investigations. Results have justified faith in the ultimate value of apparently unrelated scraps of ecological incidents patiently and meticulously recorded over many years. The mosaics constructed from these entomological tessarae reveal informative pictures of the working of natural control in natural forest; those for teak and shisham are particularly rich in detail. They explain which of the elements in a life-community and its environment contribute to the control of a pest and which are neutral; they isolate the factors that are essential for the control of an insect by natural processes. Based on such motives ecological research should prove an increasingly profitable method of solving future problems created by pests of the living tree, and, until substantial contributions are made by provincial research officers, universities or non-professional entomologists, it must remain the chief function of the Forest Entomologist. The adjustment of general principles to local conditions (by selection of pertinent factual data) must always be the task of the local forest officer, especially the working plan officer. What Trevor says of silviculture applies equally to entomology.... "research is not the perquisite of men particularly employed on this work; the greatest improvements in Indian forestry have often been made by officers living deep in the jungles of India, who have devoted themselves day by day to the study of nature around them until they have acquired an intimate knowledge of the life of forest trees which none other can possess."

Pests of timber in Industry

The instrument of instructions quoted above does not emphasise research on damage to forest products, i.e., to timber or minor produce after it has been sold and put to commercial use; nevertheless, the pests of the timber trade and wood using industries, as also the borers and termites that concern the Public Works, Railways and Army Departments, have, in practice, formed a major subject of research at Dehra Dun and must continue to do so until other agencies take over the responsibility (as has been done for lac by the foundation of the Indian Lac Research Institute in 1925). The fundamental methods of control have been worked out but the new problems arising from the increasing industrialisation of India will always need special attention.

Systematics of Indian forest insects

(By J. C. M. Gardner)

The legs of a crane-fly are long.
The legs of a lady-bird are short.
Why worry?

(Chinese proverb)

Pioneer work in forest entomology was hampered by the difficulty of obtaining names for insects collected in general surveys or in special investigations. Very little help was available in India and it is not surprising that much of the original material was misnamed. The first important steps to ensure a means of identifying insects at the Forest Research Institute were taken by A. D. Imms (p. 7) who established two fundamental requirements: an authoritatively indentified reference collection and a good library. From his time onwards despatch of insects to specialists in various parts of the world has been continuous with the result that in 1940 the collection at Dehra Dun contained 17,000 different species named by such distinguished authorities as Arrow, Baranov, Blair, Breuning, Chopard, Collenette, Corporaal, Cushman, Ferriere, Fleutiaux, Frazer, Grouvelle, Horn, Jordan, Kleine, Lesne, Marshall, Meyrick, Obenberger, Prout, Snyder, Thery, Uvarov and Waterston. It has not been possible, however, to find specialists who would undertake indentification of certain families, some of them of great economic importance; for example, biological control investigations were impeded for many years by the impossibility of naming parasitic Hymenoptera and Diptera but in recent years valuable assistance has been given by the Imperial Institute of Entomology under the directorship of Sir G. A. K. Marshall.

By 1920 it had become evident that the maintenance of the rapidly growing collection and the indentification of the enormous numbers of insects reared in the insectary, collected by field-parties and sent in with enquiries from forest officers, would require the whole time attention of a competent taxonomist. Accordingly the post of Systematic Entomologist at the Forest Research Institute came into being as related on page 9.

In considering the task of the Systematic Entomologist it may be mentioned that over 40,000 species of insects in this region (India, Burma and Ceylon) have been named and described (often insufficiently) and that an equal number* quite probably have not yet been described; names for any of these may be required urgently; some can perhaps be dealt with at once, others may require dissection and prolonged study before a decis-

*Other estimates put the number of species of the insect fauna of India at 2½ millions, we know only one species for every sixty we know not.

"In the wood down there they've got no names."

(Through the Looking Glass)

ion can be arrived at. But that is only one aspect of the question, since the classification of immature stages especially of holometabolous insects had been almost entirely ignored by classifiers and experience has shown that a large proportion of determinanda are larvae, particularly of Coleoptera and Lepidoptera. The Systematic Entomologist has, in recent years, paid particular attention to the classification of immature stages with a view to filling a serious gap in practical systematics. It may be said that most coleopterous and many lepdiopterous larvae of importance in Indian forestry are now identifiable.

The Forest Research Institute collection of about 17,000 different species is by far the strongest in the Coleoptera which form an unsurpassed collection; many new species are added from year to year. As an example of expansion in one family the subfamily Lamiinae (Cerambycidae) may be cited; the total number of Indian species listed in Junk's *Catalogus Coleopterorum* published in 1921 was about 400; by 1940 the number of Indian species had been doubled, the great majority of the new species having been added by the Forest Research Institi-titute's investigations. The Lepidoptera (including a very representative collection of Rhopalocera), the Rhynchota, Orthoptera are rather less well represented but are continually being added to. There is a good collection of termites but in the opinion of Gardner much of the descriptive work of the past has been so inadequate that a complete revision of the order Isoptera is required before accurate identifications can be provided.

Nearly all insects in the collection have been taken by the staff of the Entomological Branch and a small proportion has been obtained by exchange or presentation. Relatively few forest officers have contributed; amongst those who have specially collected for the Institute are A. E. Osmaston, H. G. Champion, R. N. De, L. Durga Dass, A. H. Khan, B. Sen Gupta, J. E. M. Mitchell, J. C. Nath, R. N. Parker, S. Rangaswami, V. S. Rao and O. H. Walters, but it must be recorded that on the whole voluntary effort of the Forest Departments has been so small as to be practically negligible.

Finance

The average annual cost of research in forest entomology in India since its start has been about Rs. 53,000 or £ 4,000; but in its most prosperous times it has budgetted just over one lakh of rupees or £ 7,650 and has employed a staff of 5 gazetted officers, 20 technical assistants, 4 clerical and 10 subordinate employees exclusive of temporary labour. In a later section (p. 29) on 'Losses caused by insect pests' it is shown that this expenditure on research has been profitable.

The following officers have held the post of Forest Entomologist (Zoologist) in an officiating capacity for more than 4 months: R. S. Hole (I. F. S., 1896–1925), N. C. Chatterjee, B. B. Osmaston, (I. F. S., 1888–1923), F. M. Howlett (A. R. I., Pusa), W. F. Perree (I. F. S., 1893–1926), D. J. Atkinson and J. C. M. Gardner. The following officers have held the post of Systematic Entomologist in an officiating capacity for more than 4 months: C. F. C. Beeson, O. C. Ollenbach, A. H. Khan (I. F. S., 1931 to date).

Organisation of forest entomology in neighbouring countries

BURMA: In Burma, except for the employment of J. M. D. Mackenzie (I. F. S., 1911–1930) for a few months in 1921, entomological research by the Burma Forest Department did not begin until 1928 when D. J. Atkinson (p. 9) was appointed Forest Entomologist; he held the post from January 1928 to March 1935. In accordance with the Government of Burma's policy, work was concentrated on the pests of teak and particularly on the beehole borer, *Xyleutes ceramica*, for which extensive ecological and economic surveys were carried out; the defoliation of teak also received considerable attention. The chief insectary was maintained at Maymyo and another was started in 1930 at Pyinmana for teak defoliators; two field-stations in other localities were used for the beehole borer. The staff included 2 or 3 field assistants and the annual expenditure varied from Rs. 20,000 to Rs. 28,000. In 1932 considerable retrenchment was considered necessary; the staff was reduced to half and work continued on a maintenance basis for some years.

In March 1935 P. F. Garthwaite (B. F. S.), who had been attached to the Branch for about a year, was appointed Forest Entomologist. The staff then included 2 Insectary Assistants and in 1937 a third Assistant was obtained. During Garthwaite's absence L. J. Vernall, (B. F. S.) was in charge of entomological research. The beehole borer and the defoliators of teak still formed the principal research projects but with greater emphasis on biological control; an insectary to study the parasitism of teak defoliators was opened in Insein in 1935 and work on this subject was closely coordinated with that in progress in India. After the

outbreak of war and the departure of Garthwaite, J.D. Braithwaite (B. F. S.) became Forest Entomologist until he too departed on military service in 1940.

Owing to the dominant claims of teak insects, the pests of other trees have received very little attention, notable exceptions being the defoliator of *Gmelina arborea* and the borers of *Xylia dolabriformis* and bamboos. Mr. Atkinson records that any other investigations that have been taken up have been side-lines, pure and simple, and, as for any systematic work or even general collecting, the number of days that have been devoted solely to this could be counted on the fingers of one hand. The major projects on teak insects nevertheless produced very large numbers of specimens needing names; the arrangements for identification and description of this material have been undertaken by the Entomological Branch at Dehra Dun in return for which assistance the Government of Burma makes a substantial annual contribution.

The organisation of entomological research in Burma with its extreme concentration on what is regarded as the economic side has evoked strong criticism in some quarters (see also Stebbing, 1939, *Empire For. Journ.*, 18, pp. 320-324). It has certainly suffered from the periodical fluctuations in the finances of the country and for some years barely survived. Despite these setbacks it has made remarkable progress in the investigation of two of the most difficult problems in tropical forest entomology. A policy that concentrates all resources on a limited number of problems is inherently sound, but it cannot reach a final solution if the ecological and physiological foundations of these problems are arbitrarily restricted.

Dependence on the information and interpretation that pure science can supply to an economic investigation is all the more vital when the investigators are primarily forest officers who get their entomological knowledge by experience rather than by training.

MALAYA: Until recent years insect pests of trees have been studied in Malaya by the agricultural entomologists. Biological studies on true forest insects, particularly the Platypodidae and Scolytidae, were started in 1933 by F. G. Browne (M. F. S.). Although the establishment of an export trade in timber has drawn the attention of the forest department to the borer-problem no official post of forest entomologist has yet been created. The Research Conservator, J. G. Watson (M. F. S.) considers that the borers of exportable timbers could occupy the full time work of a specialist but that insect damage in the evergreen rain forests of Malaya is of little silvicultural significance—an interesting contrast to the conditions which decided the appointment of a forest entomologist in India. The problem of controlling termites

in buildings and timber structures generally has received attention from the department's Wood Technologist, H. E. Desch.

INDO-CHINA: The borers of plantation trees have been investigated at experiment stations by P. Dupont. In 1927 J. Bathellier published in the *Faune des Colonies Francaises* the results of his work on the termites of Indo-China. L. Caresche of the Institut des Recherches Agronomiques at Saigon in recent years has studied the borers of dipterocarps and termites.

CEYLON: For its size Ceylon has been well endowed with economic entomologists from the time of E. E. Green, although several have served only for short contracts. Insect pests of shade trees have been studied by the Government Entomologist, J. C. Hutson, and those employed by the Tea Research Institute and the Colombo Museum. Termites have been investigated by F. C. Jepson who produced one of the earliest bulletins on the control of oriental termites.

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PART ONE

THE ECOLOGY OF FOREST INSECTS

"What does it live on?" Alice asked, with great curiosity.
"Sap and sawdust" said the Gnat. "Go on with the list"

(Through the Looking Glass)

INSECTA

THE CLASS INSECTA

THE Class INSECTA constitutes far and away the largest of all groups in the Animal Kingdom; about three-quarters of all known species of living animals are insects. Not less than 650,000 species of insects have been named and described; vast numbers of new species in addition have been collected and await description in the museums of the world. The total number of insect species yet to be discovered in the whole habitable world has been estimated by various entomologists, cautious and imaginative, at between 10 millions and 25 millions. In India many hundreds of new species are found every year; on the average 500 new species are added annually to the Forest Research Institute collection alone. At least 40,000 described species are known to be indigenous within the Indian region but only about 25,000 of them are represented in the museums of India and over 17,000 of these are preserved in the Forest Entomologist's collection at Dehra Dun (which omits many groups that are primarily of agricultural, medical or veterinary importance). These figures indicate the progress so far made in our survey of the forest insect fauna and the probable magnitude of the effort still to be made before an ecologist can construct a detailed design of each important biocoenosis.

In this book are assembled over 4,300 species of forest insects but this quantity is a selection and does not include every species of which the food or feeding-habit is known; it does include at least one representative species of every type of locality-plant-insect combination found in Indian forests; it includes every species that has been the subject of an enquiry or expression of interest by a forest officer of the Indian Empire. Generalizations or summaries of this mass of factual details have been attempted by the author and are offered to the forester who should accept them with reserve. The reduction of a diversity of data to the form of a universal generalization is liable to present a false simplicity. Each forest division needs its own special generalizations.

Phylogenetic classification of the Insecta

The phylogenetic classification of the Insecta is given in the following synopsis which shows the sequence of the Orders as suggested by Mr. J. C. M. Gardner, Systematic Entomologist, who has also provided the synopses of the classification and phylogenetic sequence adopted in subdividing the Orders. They agree in essentials with most textbook classifications but differ in some details of sequence and nomenclature.

CLASSIFICATION OF THE INSECTA

Class INSECTA

Subclass **APTERYGOTA**	Subclass **PTERYGOTA**
Order **Protura**	Order **Orthoptera**
Thysanura	**Dermaptera**
Collembola	**Plecoptera**
	Isoptera
	Embioptera
	Psocoptera
	Mallophaga
	Anoplura
	Ephemeroptera
	Odonata
	Thysanoptera
	Rhynchota
	Neuroptera
	Mecoptera
	Trichoptera
	Lepidoptera
	Coleoptera
	Strepsiptera
	Hymenoptera
	Diptera
	Siphonaptera

What is a forest insect?

What is a forest insect? Quite simply it is an insect which lives in a forest; in the terminology of terrestrial synecology it is a member of a forest biocoenosis. The basic idea of the biocoenosis or life-community must be introduced at the very outset of a study of forest insect life. A biocoenosis is an

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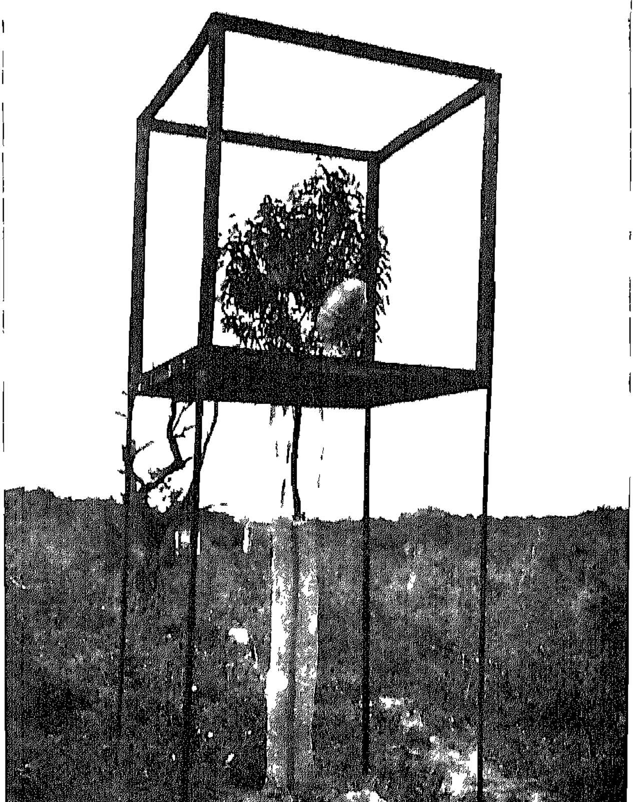
Fig. 1. Cages used for ecology of sapsuckers

Above Battery of cages used for the study of sap-suckers of of sandal; the angle iron frame is covered with wire gauze or cloth with a sleeve (white circle) for manipulation; the plants are in 4 pots and their stems enter the cage through holes in the floor.

Below— Sandal tree enclosed in a wire-gauze covered frame supported on angle irons; base of wood; stem enclosed in wire gauze cylinder.

2



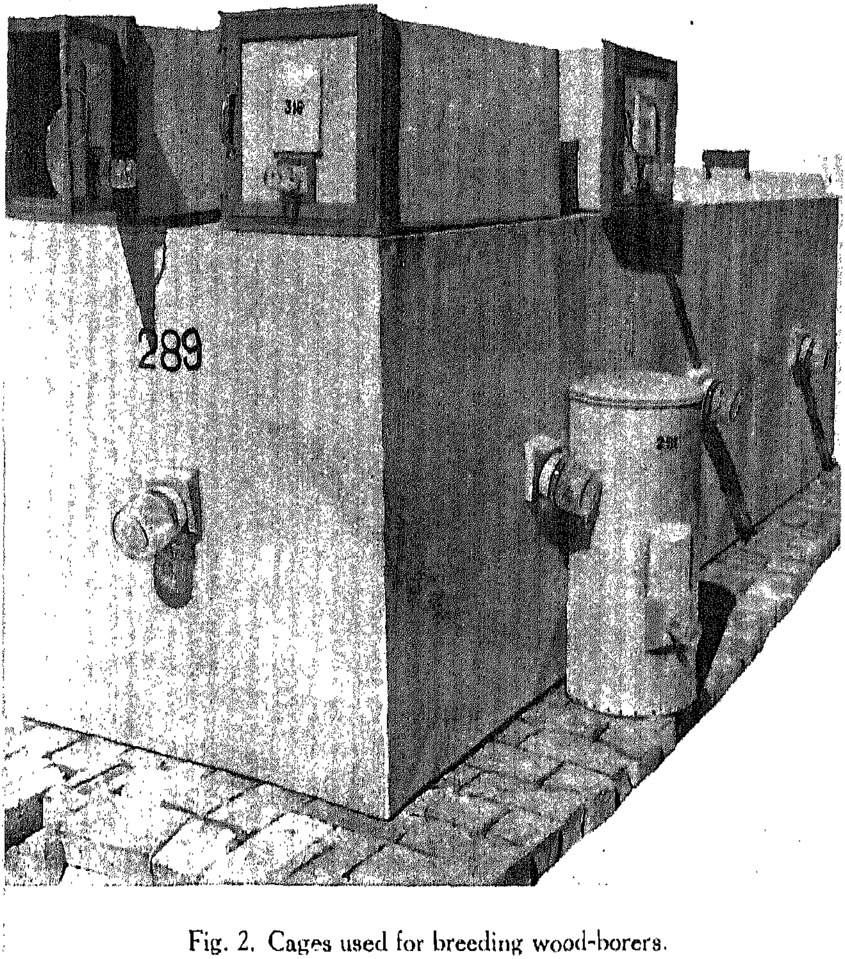


Fig. 2. Cages used for breeding wood-borers.

Made of galvanised iron with the joints overlapped and soldered and rivetted; fitted with wooden blocks carrying screw-top wide-mouthed glass jars acting as light-traps; doors hinged to flush-fitting wooden frame, the surfaces in contact lined with velvet or felt. Cage 316 measures $2' \, 3'' \times 1' \, 1'' \times 1' \, 1''$; cage 289 measures $10' \times 3' \times 3'$ and the floor is fitted with a frame carrying wooden rollers so that heavy logs may be slid in and out.

association of living organisms (plants and animals) which are mutually dependent upon each other; their dependence is so closely interlocked that a biological balance is produced—a balance which is unstable, it is true, but which is self-regulating towards a mean. The animals in the forest biocoenosis are dependent on the plants; the plants are most directly dependent on the locality but they are also dependent on the animal-communities. Forest insects, therefore, should not be studied as entities apart from the other members of the whole life-community, nor can an insect species which is a pest, be isolated, and be fully understood without reference to other species in its association or food-chain.

A forest officer may contend that the only kind of forest insect that need concern him is one which causes intolerable damage to the species of tree he wants to grow. Leaving out of account for the moment those insects that assail his own person (e.g., biting flies) and those that produce revenue (e.g., the lac insect) we may examine this contention further. It is a quite a rational attitude for the practical forester who is content to practice the methods of his predecessors. Under standardised and inflexible conditions of forest management he is justified in expecting the forest entomologist to analyse the problem and present him with its simplified essence. The forest pest need not be more than a name or a label for a set of symptoms and an appropriate set of remedial measures. But Indian forestry is not static to such an extent; it is experimental and progressive and is continually producing new conditions under which well-known pests create fresh ecological problems and unknown insects spring into prominence as pests. Tropical forestry has to build up its own silvicultural science but it will not do so by ignoring completely the ecology of its insect pests. Silviculture under such conditions will be a race between the emergence of new pests and the discovery of new technique for their control.

A proper conception of the causes of insect damage in forests cannot be obtained without reference to the associates, competitors and enemies of an insect pest. This book therefore presents all the ecological data available on the forest insects of India and the adjoining territories, together with the principles by which the data are converted into measures for the control of the tree and its pests. To the forester, and particularly the working plan officer, dealing with a limited area, the actual details should be of more value than the false simplicity of generalizations. It is for them to examine the data provided by entomology, select the facts pertinent to their local problems and add the missing details, until finally they evolve for themselves the generalization appropriate to the case.

A forest insect pest is a member of a forest biocoenosis.

What does it live on ?

The most important characteristic of a forest insect is its food. The food of insects ranges between the extremes of a famishing diet like dry cellulose and the rich nourishment of warm human blood, and includes such unlikely matter as strychnine and opium. Food-habits can be classified in the following categories according to the nature of the food-stuff; but the categories are transitional rather than exclusive, and they may occur in combination in the diet of a single species of insect; they form useful descriptive terms.

1. HERBIVOROUS, or phytophagous, i.e., feeding on plants or matter of vegetable origin.
2. PUTRIVOROUS, or saprophagous or scavenging, i.e., on decaying organic matter and the fungi or moulds associated with fermentation and putrescence.
3. CARNIVOROUS, or predaceous or parasitic, i.e., feeding on living animals or on recently killed animal matter as predators or parasites.
4. OMNIVOROUS, or pantophagous, i.e., on all kinds of miscellaneous vegetable and animal matter.

(Note. The terms "polyphagous," which means feeding on *many* kinds of food, "oligophagous" = feeding on *few* kinds of food and "monophagous" = feeding on *one* kind of food, are terms used to qualify the categories 1, 2 and 3).

One can classify the activities of these four groups of forest insects according to (a) taxonomic position of the insect, or (b) the part of the plant (or forest) eaten, or (c) the physiological condition of the plant or animal affected (e.g., healthy, diseased, dead). A classification based on a combination of (b) & (c) gives a more general view of the food-habits commonly characteristic of the various families and orders of the class Insecta. The following tabulation is by no means a complete list but serves to show that a feeding habit or type of injury to plant or animal is not exclusively characteristic of one family or one group but may be exhibited by diverse and unrelated groups.

I. HERBIVOROUS INSECTS

LIVING TREE

Eaters of buds and flowers; pollinators

COL. Melo. Scarabae; DIP. Itonid. many families; HYM. Ap.; LEP. Eucosm. Tortric. many families; RHYN. Psyll.; THY. most families.

Eaters of seeds and fruits

COL. Anthrib. Bruch. Curculion. Cerambyc. Scolyt.; DIP. Agromyz. Itonid. Trypet.; HYM. Chalc. Cynip.; LEP. Blastobas. Carposin. Eucosm. Pyral.

Borers

Shoot-borers: COL. Bostrych. Buprest. Cerambyc. Chryso-

mel. Curculion. Mordell.; LEP. Blastobas. Coss. Gelechi. Oecophor. Pyral.

Stem-borers (bole, trunk and large branches): COL. Bostrych. Buprest. Cerambyc. Curculion. Platypod.; LEP. Coss. Hepial. Indarbel.

Collar-borers and Root-borers: COL. Cerambyc. Curculion. Scolyt.

Defoliators

Leaf-eaters: COL. Chrysomel. Coccinell. Curculion. Scarabae.; HYM. Tenthredin.; LEP. almost all families; ORTH. Acrid. Gryll. Phasm. Tettigoni.

Leaf-rollers: COL. Curculion.; LEP. Pyral. Eucosm.

Leaf-miners: COL. Buprest. Chrysomel. Curculion.; DIP. many acalyptrate families; LEP. many microlepidopterous families.

Sap-suckers

LEP. Noctu.; RHYN. practically all families; THY. practically all families.

Soil and Ground-dwellers

Cockchafer grubs, cutworms, wireworms, crickets, etc.: COL. Curculion. Elater. Scarabae.; DIP. Asil. Psychod. Tipul.; LEP. Noctu.; ORTH. Acrid. Blatt. Gryll.

Termites and Ants: HYM. Formic.; ISO. all families of ground-dwelling termites.

DEAD TREE

Borers of Bark or Log

COL. Anthrib. Bostrych. Brenth. Buprest. Cerambyc. Curculion. Elater. Eucnem. Lymexylon. Platypod. Scolyt.; HYM. Siric. Xiphydri. Xylocop.; LEP. Tine.

Borers of Converted or Manufacted Timber,

Powder-post beetles, etc.: COL. Anobi. Bostrych. Cerambyc.; **Termites:** ISO. all families.

2. PUTRIVOROUS INSECTS

Decaying vegetable matter

COL. Anthic. Cryptophag. Endomych. Nitidul. Tenebrion.; COLLEM. most families; DER. some groups; DIP. Anthomyi. Bibion. Musc. Mycetophil. Phor. Sapromyz. Trypet.; ISO. all families; PSOC. all families; THYSANURA.

Decaying animal matter

Skin, flesh, bone, etc., COL. Dermest. Hister. Nitidul. Silph. Staphylin.; DIP. Calliphor. Musc. Mycetophil. Phor. Seps.; HYM. Formic.; ISO. all families; LEP. Tine.; ORTH. Blatt. Gryll.

Excrement: COL. Scarabae. Staphylin.; DIP. Calliphor. Musc.

3. CARNIVOROUS INSECTS

Predators

COL. Carab. Cicindel. Cler. Coccinell. Elater. Hister. Staphylin. Lampyr.; DERM. some groups; DIP. Asil. Phor. Syrph. Taban.; HYM. Eumen. Sphec. Vesp.; LEP. Blastobas. Lycaen. Noctu. Tine.; NEUR. Chrysop. Hemerobi. Myrmelon.; ODO. all families; ORTH. Acrid. Blatt. Gryll Mant.; RHYN. Anthocor. Belastom. Nep. Pentatom. Phymat. Reduvi.

Parasites

COL. Colydi. Melo. Mordell.; DIP. Bombyl. Calliphor. Oestr. Phor. Tachin.; HYM. Chalcidoidea, Bethyloidea, Ichneumonoidea, Serphoidea, Scolioidea.

Blood suckers (Vertebrate blood).

ANO. All families; DIP. Anthomy. Culic. Psychod. Simuli. Taban.; RHYN. Cimic.; SIPH. all families.

4. OMNIVOROUS INSECTS

HYM. Formic.; ORTH. Blatt.

Classifications on somewhat the same lines are given by Lefroy, 1909, *Ind. Ins. Life*, pp. 27–34.

Life-cycle, generation and brood

The terms 'life-cycle', 'generation' and 'brood' are used rather loosely in the literature of economic entomology. Strictly defined, the **life-cycle** is a time-period which begins with fertilization and ends with the death of the adult insect and is synonomous with the **longevity** of the individual. For practical purposes life-cycle means *the period elapsing between the points of time at which the egg is laid (or the larva is born viviparously) and the resulting imago emerges freely and actively.* In the majority of insects, the free emergence of the imago coincides with emergence from the pupa or preimaginal stage but in insects living in concealment, such as wood-borers, soil-insects, gall-insects, etc., emergence means escape from the wood or soil or galls, and occurs some time after the imago has transformed from its pupa. Occasionally the time elapsing between the emergence of the imago and the deposition of the first egg by the fertilized female is a fairly uniform period and is readily determined. The term life-cycle is then extended to cover the period from deposition of the egg to deposition of the first egg of the next generation; i.e., the whole pre-reproductive period of the insect; this period may be termed the **complete life-cycle.**

Limits and subdivisions of life-cycle.

The life-cycle is therefore composed of the following points and periods of time: -

Fertilization of the Egg
|
Deposition of the Egg
|
Larval and Pupal Periods or Nymphal Period
|
Emergence from the Pupa or Preimaginal Stage
|
Resting Period of Imago
|
Free Emergence of Imago
|
Fertilization of the Egg
|
Deposition of the Egg
|
Death of Individual

Complete Life-cycle

LIFE-CYCLE

Individual Longevity or Theoretical Life-cycle

The duration of an insect's life cycle (or its theoretical or its complete life-cycle) is not a period of time constant for each species and each individual of the species. It may vary considerably above and below an average under the influence of various factors of the environment, particularly of temperature and humidity (pp. 799 803).

The term **generation** is used to describe all the individuals of a species in a particular locality that are the offspring of an immediately previous generation. For this conception it is usual to choose as starting-point a season of the year marking a definite break in the continuity of insect activity; generally the beginning of the calendar year serves the purpose, but in special cases the beginning of the monsoon season or of the dry season may be chosen. In this book the 1st January is used to divide one biological year from the next. The generation starts when the egg is deposited.

All the individuals of a species hatching from eggs, or produced viviparously, after the beginning of the year constitute the **first generation** of the year. If the species has passed the winter as larva, nymph, pupa or imago, those hibernating individuals are considered to belong to the last generation of the previous calendar year. If the species has hibernated in the egg-stage it may be convenient to consider those eggs as forming part of the first generation of the new year, but in such cases it is the instar which hatches that marks the true beginning of the generation.

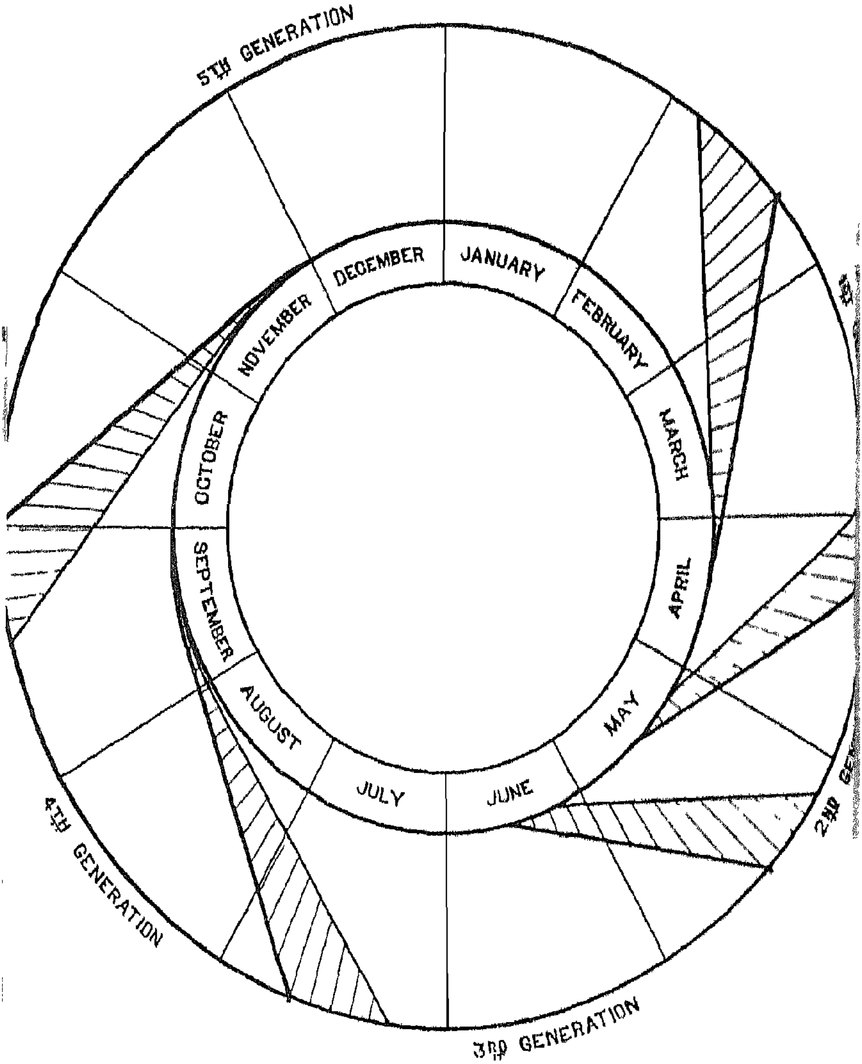


Fig. 2A, Annual succession of generations in the Toon Shoot-borer, *Hypsipyla robusta.*

The period of time during which the first generation persists, lasts from the date of deposition of the first egg until the date of emergence of the last imago from a first generation egg; (or until the date of deposition of the last egg by the last imago of the first generation, if complete life-cycles are adopted). All individuals hatching from the eggs laid by the imagines of the first generation constitute the **second generation** and their progeny

constitute the **third generation** and so on.

Owing to the variation in the length of the egg-laying-period and the emergence-period, and in the rate of development of the different stages in the life-cycle, it is evident that the quickest rate of development may considerably outstrip the slowest rate of development. In the course of a few generations this divergence may be so great that some of the individuals of one generation are in existence at the same time as some of the individuals of the corresponding instar of a previous generation. When this occurs the generations are said to *overlap* completely.

The diagram given in figure 2A shows the annual succession of generations in the Toon-Shoot-borer, *Hypsipyla robusta*. In north-west India there are normally 5 generations in one year which gradually overlap until nearly all the instars of one generation may be found on the same date, e.g., larvae, pupae and moths of the 3rd generation, and eggs and larvae of the 4th generation on the 1st August; or similar instars of different generations may be found on the same date, as for example, larvae of the 1st and 2nd generations together on the 15th April, or larvae of the 2nd and 3rd generations together on the 20th May. From the casual collection of a specimen in the field it is not possible to decide with certainty to which generation it belongs.

Another method of illustrating graphically the life-history and sequence of generations is by use of hyperbolae in a triple band for maximum, average and minimum limits.

The term **brood** is restricted to a portion of the total number of individuals comprising a generation. (a) Females of species that have a long oviposition-period may lay their eggs in batches at intervals; often these intervals may be separated by a period of feeding or further maturation of the ovaries or repeated copulation. Each batch of eggs gives rise to a separate well-defined group of individuals, i.e., brood. The sum of all the broods of all the females constitutes a generation. (b) An evenaged brood of eggs may produce larvae that vary greatly in their rate of maturation, so that well defined broods of adults may result at distinct intervals. The sum of all such broods constitutes the same generation. Some entomologists recognise that a brood may be composed of individuals of 2 or more overlapping generations, e.g., a species with long-cycle and short-cycle generations of 6, 12 and 18 months duration can produce at the end of 18 months a brood of adults composed of the broods of 3 generations; and their eggs will constitute a single generation, the first of the year.

The length of life-cycles

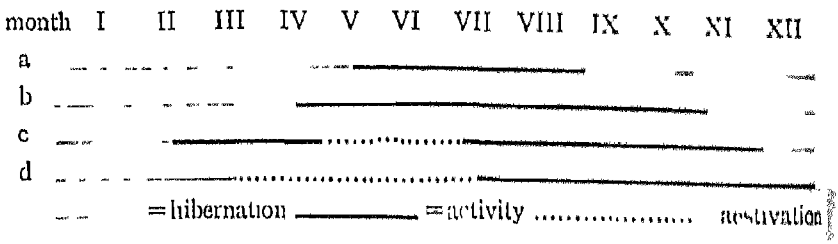
Insect life-cycles can be grouped according to their length in 3 classes:—(a) longer than a year, (b) annual, and (c) shorter than a year.

(a) Life-cycles that are longer than a year usually owe their length to the prolongation of the larval or nymphal period, and rarely to a disproportionalely long egg or pupal period. The longest insect life-cycle known is that of a cicada. The longest recorded larval stage of an Indian forest insect is that of *Stromatium barbatum*, p. 208. The longest adult life is that of a queen termite.

(b) The annual life-cycle extends from a season in one year to the corresponding season of the next year and lasts for 365 days, more or less. It is the normal cycle for insects in temperate climates where the period of activity and feeding is restricted by the seasons. The rhythm of existence is definitely annual, so that if weather conditions during the active period increase or decrease the lengths of these stages, this variation is compensated by a corresponding decrease or increase in the dormant period.

(c) Life-cycles which are shorter than a year show a range from 2 to 20 or 30 per annum. For any particular species of insect the duration of the life-cycle depends on many environmental factors of which the chief one is always temperature. Humidity as well as quantity and quality of accessible food are important factors but their importance is small as compared with that of temperature in determining the variation from the normal life-cycle of the species (Bodenheimer). The number and sequence of life-cycles during the course of one year is not directly proportional to the temperature; the periods occupied in hibernation and/or aestivation vary with each species.

The diagram below shows variation in the seasonal history (sequence of generations) due to different climates in different parts of the habitat of a species



(a) represents the life-history in a temperate climate with one generation a year and a long period of hiberation

(b) in a warmer climate the period of hibernation is reduced and the active period includes 3 generations

(c) in a climate with a torrid hot season aestivation follows after a spring generation and there are 3 post-aestival generations until hibernation begins

(d) represents the sequence where there is a continuous period of inactivity from hibernation to aestivation; the post-aestival period may comprise one generation only or several generations (in different species).

ON LOSSES CAUSED BY INSECT PESTS AND ENTOMOLOGICAL PROPAGANDA

"I can't believe that!" said Alice

"Can't you?" the Queen said in a pitying tone. "Try again: draw a long breath and shut your eyes."

Alice laughed. "There's no use trying," she said: "one can't believe impossible things"

"I dare say you haven't had much practice," said the Queen "When I was your age, I always did it for half-an-hour a day Why, sometimes I've believed as many as six impossible things before breakfast" (Through the Looking Glass).

In these days when all propaganda is suspect, even the self-defensive arithmetic of economic entomologists has an air of impossible things. Insect-loss statisticians adopt the simple method of applying a definite percentage to the crop values in order to demonstrate the losses due to insects. For particular crops or products the average annual percentage lost lies between ½ and 30. The conventional value for the flat rate percentage is 10, which general experience proves is a fair estimate of the average annual loss. But every statistician recognises that there is an economic fallacy in estimates obtained by this method, because a decrease in production is ordinarily followed by an increase in price.* This discrepancy is less important in forestry where market prices of timber are rarely affected by annual fluctuations in the abundance of pests, and the expected yields of forests are calculated on the increment of trees which have been perenially affected by insects. On this basis an instructive comparison can be made of the losses caused to forestry and to human industries generally in India and in other large countries.

The grand total of the estimated annual loss due to insects affecting agricultural crops, forests and forest products and stored products in some large countries is given in the following statement.

Figures in *millions* of dollars, pounds and rupees.

Country	*Authority*	$	£	Rs.
U.S.A.	Howard 1931	2,200	440	5,770
,,	Hinds 1934	2,500	500	6,560
Canada	Imp. Ent. Confce. 1930	150	30	390
Australia	,,	100	20	260
India & Burma	Fletcher 1921	697	140	1,850

*In the case of annual crops liable to over-production and the problem of disposal of surplus, it is possible to argue that the fraction destroyed by insects does not constitute a financial loss to the grower owing to the readjustment of market prices to the actual yield. Such a loss should be quoted in quantities of crop not in its money values.

The annual loss in India and Burma is thus 185 crores of rupees. If we add the loss in human mortality due to insect borne diseases in India with Burma to that caused by insects attacking agricultural crops, forests and animal products the total amount cannot be less than 260 crores of rupees a year. The Malaria Bureau states that the economic loss to India from deaths due to malaria alone is between 45 and 90 crores. For losses to forests and forest products alone the estimated figures for the U.S.A. may be compared with those for India and Burma.

FORESTS. Figures in *millions* of dollars, pounds and rupees.

Country	Authority	$	£	Rs.
U.S.A.	Metcalf and Flint 1920	130	26	340
"	*Bureau of Entomology 1933*	*150*	*30*	*390*
India and Burma	Fletcher 1921	47	0'05	12'5

The annual loss of 125 lakhs of rupees for the forests of India and Burma is assessed at Rs. 100 per square mile of a restricted workable forest area; it represents a very high percentage of the gross revenue. If the estimate is based on the gross revenue plus the value of the produce supplied free to the population, and the normal 10 percent depreciation is applied, the figure for the loss is considerably reduced, i.e., 49 lakhs (for 1936 37) or about 1 anna per acre per annum. But if we consider the actual and potential losses caused to forests by particular species of insects and use actual or experimental data, it appears that an assessment on an acreage basis gives a truer indication than an assessment on revenue which takes account only of what is exploited and ignores what is abandoned as a total loss. Undoubtedly more forest capital is destroyed by pests, diseases and fire than is utilized.

The following examples illustrate the variation in value and extent of damage caused by some of the major pests of Indian forestry :—

i. *Hoplocerambyx spinicornis*, the sal borer. The recurrent annual damage has been estimated at Rs. 2½ lakhs on sal timber extracted from state forests alone; or an annual loss of 2 annas per acre on the outturn of a million acres in the United Provinces alone. During epidemics the loss rises, e.g., to an average of Rs. 18 per acre. In the peak year of the calamity which affected five forest divisions in the Central Provinces, a neighbouring Indian State and much private land, the loss of forest capital was over 137 lakhs of rupees, or £1,044,000, i.e., exceeding the supposed normal total loss for the forests of the whole of India and Burma (Beeson and Bhatia, 1939).

ii. *Hypsipyla robusta* and *Pagiophloeus longiclavis*, both borers of *Cedrela toona* and *Swietenia macrophylla*. Where young plantations of these species have been written off because of borer-attack the expenditure wasted is between Rs. 15 and 30 per acre.

iii. *Plecoptera reflexa*, the shisham defoliator. In some of the irrigated shisham plantations this defoliator has completely frustrated attempts to grow a pure crop of shisham and failure has incurred losses of Rs. 20 to 40 an acre; in established crops the annual yield over 46,500 acres is reduced by a third to a half.

iv. *Hapalia machaeralis* and *Hyblaea puera*, the teak defoliators. The severest epidemics of teak defoliators cause a loss of Rs. 130 per acre in fully stocked first quality teak plantations with a royalty of Rs. 2 per cubic foot. (Champion, 1934). In such crops the normal annual defoliation is estimated at Rs. 20-25 per acre per annum. In V or IV quality teak forests with a royalty of 8 annas per cubic foot the loss may not be more than 1 or 2 rupees per acre per annum.

v. *Calopepla leayana*, the defoliator of *Gmelina arborea*, was one of the chief factors causing the abandonment of plantations in Burma having a capital value of over 4½ lakhs of rupees, i.e., a loss of Rs. 280 per acre (Hopwood, 1934, Garthwaite, 1939).

vi. *Xyleutes ceramica*, the beehole borer of teak. In Burma the value of the annual outturn of teak is reduced by 10-15 percent by the beehole borer, which loss has been estimated at about 10 lakhs of rupees to Government and the same to the buyers of the timber. (*Rodger*, in Beeson, 1921).

vii. *Laccifer lacca*. The insect enemies of the lac crop destroy between 30 and 40 percent annually; when stick lac is worth about Rs. 20 a maund this means an annual loss of 75 lakhs of rupees (or £570,000) on the total production of stick lac in India and Burma.

viii. *Spike disease of sandal*, which is a virus disease transmitted by insects, has caused a loss of nearly 300 lakhs of rupees or over two and a quarter million pounds sterling in Coorg, Mysore and Madras during the past 40 years; and about 10 lakhs a year nowadays.

These illustrations should suffice to show that losses due to insect pests may be small and possibly tolerable in poor types of forest, but they increase as the productivity of forests is increased and (as Ribbentrop foresaw 40 years ago) will become more intense in future.

Costs and assets of research

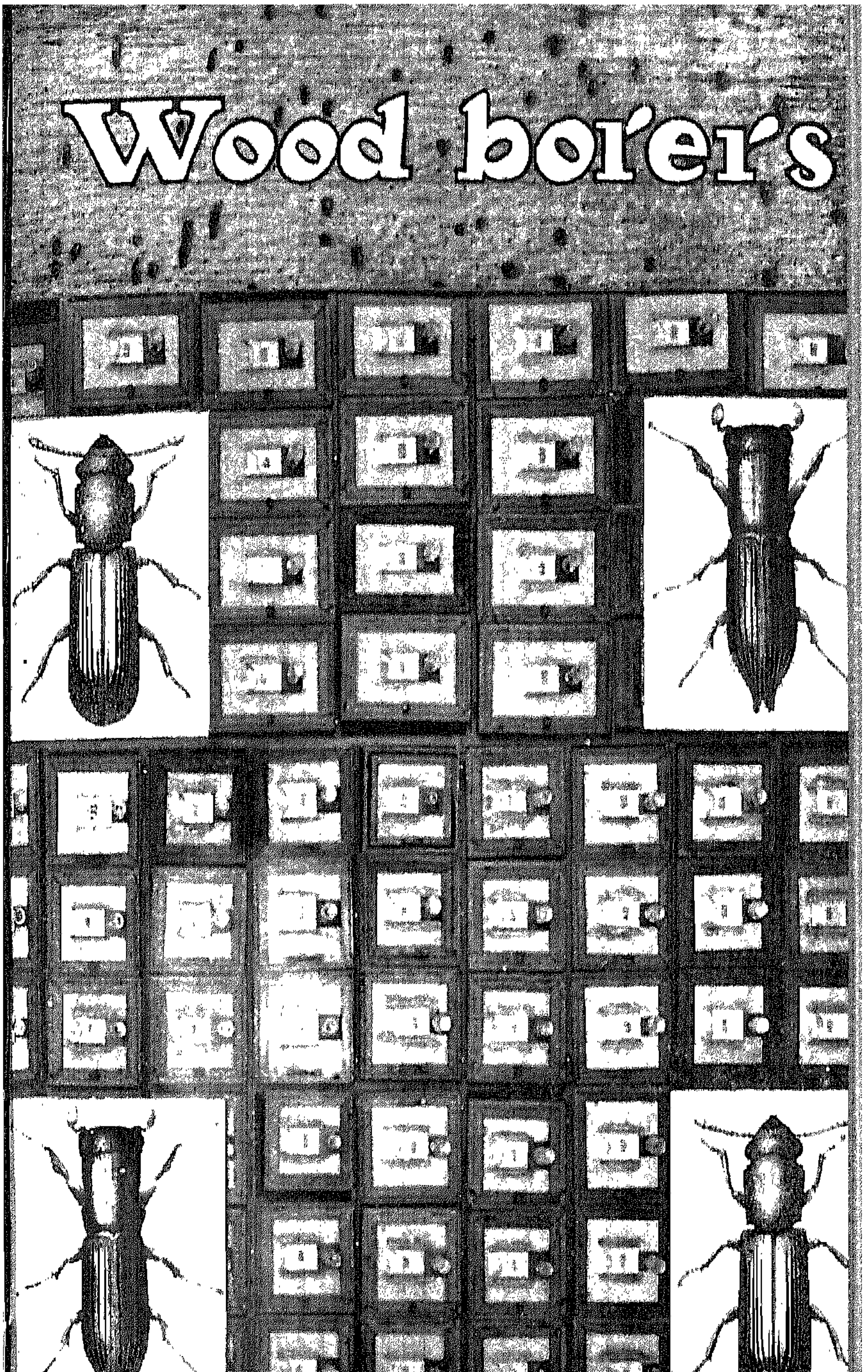
Part Two is devoted to ways and means of offsetting this menace, the discovery of which is the objective of entomological research. The control measures that have been devised supply the answer to the perennial question 'Is expenditure on research justified?'

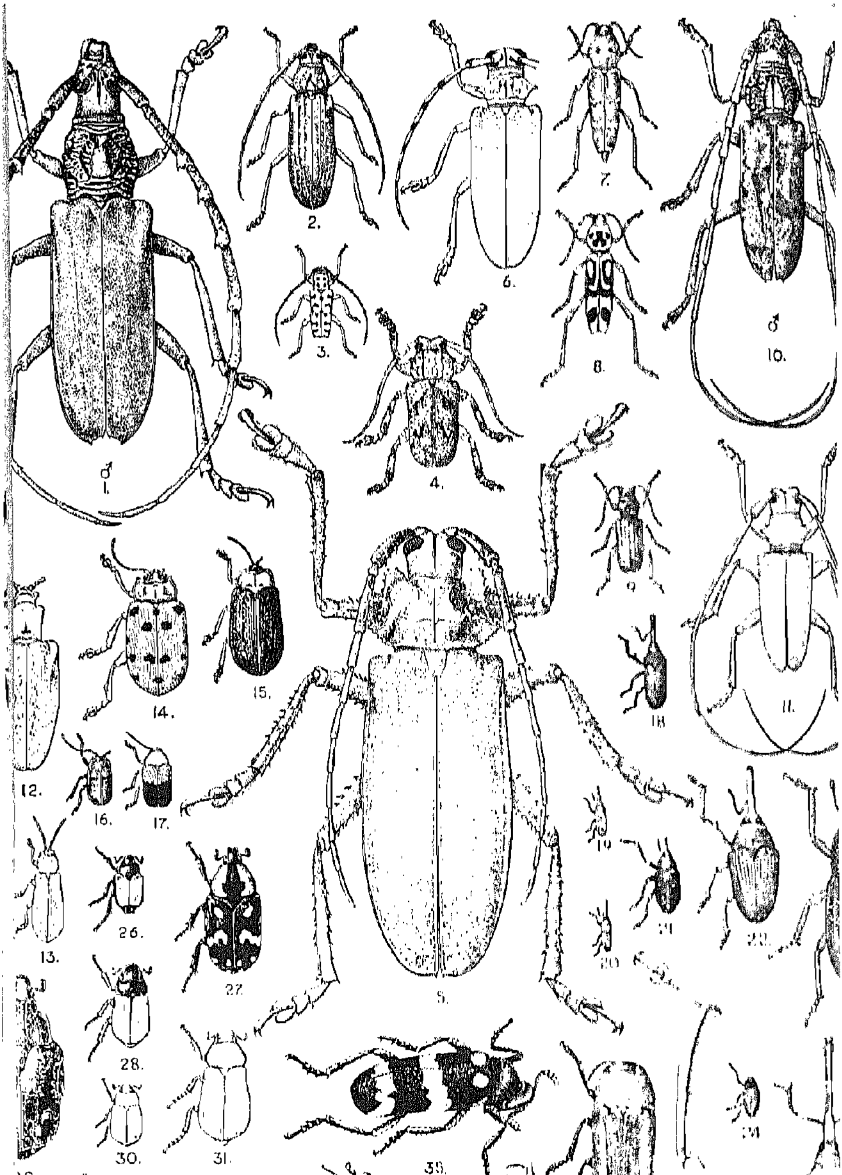
The total expenditure on the Entomological Branch of the Forest Research Institute during the past thirty years is Rs. 16,00,000; this covers research in India up to date and in

Burma up to about 1928. To assess the net cost of research one should deduct from this total the salaries of staff employed part time on educational work in the Forest Colleges and the material assests, viz., the entomological collection of some 17,000 species, the library and two museums, which together have a very high permanent value. If this balance is regarded as an investment on *which one might expect a return of 10 percent compound interest* plus the original capital, it will be evident that the whole amount involved is less than the loss that can be caused by a single major epidemic of the sal borer. It is claimed that at least one such epidemic has been prevented by knowing how to prevent it; it is concluded that the outlay on research has thereby been recouped. All the additional knowledge gained about the control of hundreds of other pests of forests and forest products can be regarded from the financial viewpoint as net profit available for financing future research.

"I can't believe that!" said Alice.

Fig. 3—Cages used in the INSECTARY of the Forest Entomologist for the study of insects damaging timber. Inset are beetles of *Platypus solidus*, a pinhole borer of green timber, and *Lyctus africanus*, a powder-post borer of seasoned timber. The background to the title is pinholed wood, natural size.


Wood borers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♀ 60.
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Fig. 4. BEETLES OF 63 SPECIES OF COLEOPTERA

All figures are natural size

1 Hoplocerambyx spinicornis, male, Cerambyc
2 Stromatium barbatum, Cerambyc
3 Glenea multiguttata, Cerambyc
4 Coptops aedificator, Cerambyc
5 Remphan hopei, Cerambyc
6 Celosterna scabrator, Cerambyc
7 Xylotrechus smei, Cerambyc
8 Chlorophorus annularis, Cerambyc
9 Tetropium oreinum, Cerambyc
10 Aeolesthes holosericea, male, Cerambyc
11 Dihammus cervinus, male, Cerambyc
12 Sagra longicollis, Chrysomel
13 Estigmena chinensis, Chrysomel
14 Podontia 14-punctata, Chrysomel
15 Calopepla leayana, Chrysomel
16 Colasposoma asperatum, Chrysomel
17 Cryptocephalus sexsignatus var., Chrysomel
18 Alcides gmelinae, Curculion
19 Calandra glandium, Curculion
20 Calandra rugicollis, Curculion
21 Cryptorhynchus rufescens, Curculion
22 Alcides crassus, Curculion
23 Sipalus hypocrita, Curculion
24 Rhadinomerus diversipes, Curculion
25 Cyrtotrachelus longipes, Curculion
26 Popilia pilosa, Scarabae
27 Clinteria klugi, Scarabae
28 Adoretus bimarginatus, Scarabae
29 Protaetia neglecta Scarabae
30 Apogonia clypeata, Scarabae
31 Lachnosterna serrata, Scarabae
32 Holotrichia problematica, Scarabae
33 Holotrichia tuberculipennis, Scarabae
34 Epicauta ruficeps, Melo
35 Mylabris pustulata, Melo
36 Psiloptera fastuosa, Buprest
37 Chrysobothris indica, Buprest
38 Buprestis geometrica, Buprest
39 Agrilus beesoni, Buprest
40 Acmaeodera kerremansi, Buprest
41 Trachelizus bisulcatus, Brenth
42 Cyphagogus westwoodi, Brenth
43 Baryrrhynchus miles, male, Brenth
44 Mesoplatypus sp., Platypod
45 Diapus furtivus, male, Platypod
46 Crossotarsus saundersi, male, Platypod
47 Platypus solidus, male, Platypod
48 Platypus cupulatus, male, Platypod
49 Crossotarsus bonvouloiri, male, Platypod
50 Ips longifolia, Scolyt
51 Diamerus ater, Scolyt
52 Xyleborus major, fem, Scolyt
53 Polygraphus major, Scolyt
54 Sphaerotrypes siwalikensis, Scolyt
55 Xyleborus noxius, fem, Scolyt
56 Xyleborus testaceus, fem, Scolyt
57 Ptilopodius ramosus, Scolyt
58 Sinoxylon crassum, Bostrych
59 Sinoxylon anale, Bostrych
60 Heterobostrychus aequalis, fem, Bostrych
61 ditto. male, Bostrych
62 ditto. side view
63 Xylothrips flavipes, Bostrych
64 Lyctus africanus, Bostrych
65 Dinoderus brevis, Bostrych

(SEE OPPOSITE PAGE)

ANOPLURA

THE ORDER ANOPLURA

THE order ANOPLURA is small, in all perhaps 150 species distributed in four families, consisting of nothing but lice—the sucking lice of men, monkeys, cattle and hogs but not the biting lice of birds (which are classed in the order Mallophaga).

LITERATURE ON ANOPLURA:

Fletcher T. B., 1926, *Agr. Res. Inst., Pusa*, Bull. No. 162 (Key).
Patton W. S. and Cragg F. W., 1913, *A text book of medical entomology.*
— W. S. and Evans A.W., 1929, *Insects, ticks, mites and venomous animals of medical and veterinary importance. Part 1, Medical.*

HAEMATOPINIDAE

Haematopinus spp. include the lice of swine, buffalo, cattle and rats. The eggs or eggshells of the hog louse, *H. suis*, are sometimes observed on the hairs of brushes manufactured in India from hog's bristles.

HAEMATOMYZIDAE

Haematomyzus elephantis. 2-3 mm. long, is the louse of the Indian elephant.

PEDICULIDAE

Pedicinus spp. include the lice of monkeys.

Pediculus humanus. The lice affecting human beings are the head louse, the body louse and the pubic or crab louse. The head and body lice are similar in appearance with no constant morphological differences and they produce fertile offspring when artificially crossed, but their habits are very distinct; for these reasons the two forms are considered to be subspecies or biological races, *P. humanus* **capitis**, the head louse, and *P. humanus* **corporis**, the body louse, the former infesting the scalp under shelter of the hair of the head, and the latter feeding on the body under shelter of clothing. Other species are not found on man although variations in colour, etc., occur; lice from the darker races of mankind are of a much darker tint than those from white skinned races, the colouration affecting the chitinised plates at the sides of the abdomen and the sternum. The range in size is 1·8—3·5 mm., the male smaller than the female and the head louse on the average smaller than the body louse.

The life-cycle of *P. humanus* in India from the time the egg is laid until the adult stage is reached takes about 3 weeks (egg period 5-7 days, nymphal period with 3 moults 14-21 days) and the adult lice may live for 3 or 4 weeks. A female lays up to 10 eggs a day and 200 to 300 in the course of her lifetime; the egg is attached by an adhesive to a hair or a fibre of the clothing. The

body louse is less abundant in the tropics owing to the lesser amount of clothing worn as well as to the higher air temperatures which cause exhaustion and death; the head louse is very common; commoner on children than adults and most so on girls with long hair in south India (Patton).

Human lice have been incriminated as carriers of relapsing fever (due to a spirochaete), typhus fever (a bacterial disease) and the so-called trench fever.

For control see Part Two, Anoplura.

Phthirius pubis. The pubic or crab louse infests the crotch or fork of the legs, the armpits and also but more rarely other hairy parts of the body. The life-cycle takes 3 to 4 weeks (egg period 6-8 days, nymphal period 14-21 days).

COLEOPTERA

THE ORDER COLEOPTERA

Beetles or coleoptera form the largest order in the animal kingdom and contain nearly a quarter of a million known species, which is equivalent to about 40 percent of the insect fauna of the world. Considered in terms of the number of injurious species this order is of greater importance than others to forestry; it also includes the potentially most important single pest species. The habits of the many different sorts of beetles are so diversified that representatives of the order may be found in every main type of environment suitable for the existence of insects. The dominant groups of beetles are those feeding on organic vegetable refuse in the humus and the soil; those feeding on wool, fur, hides, stored products; the dung and carrion beetles; the borers of bark, wood, roots, shoots, fruits or seeds; the defoliators and leaf-miners; truly predaceous and carnivorous beetles; water beetles; virtually none attack the larger animals and very few are true parasites. "Not to know something about the beetles is to remain in ignorance of a large and very interesting part of our environment" (Metcalf and Flint).

Practically all the adult beetles can be recognised by the specialised and sclerotised forewings, or *elytra*, in conjuction with the form of the prothorax; but unobservant students habitually mistake some Dermaptera and Capsidae for beetles. Variation in size is from less than one millimetre to a body-length of 3 inches with antennae or legs still longer.

Some general reference books: A most useful manual for the classification and characters of families of Indian beetles is Fowler's general introduction to Coleoptera in the Fauna of British India, 1912. Stebbing's *Indian Forest Insects of Economic Importance*, 1914, is actually restricted to the Coleoptera; although dealing with only a quarter of the number of species of

beetles listed in this book it is still good value for the sake of its illustrations. Lefroy, 1909, based largely on agricultural species is not so informative on Coleoptera as on other orders. Fletcher, 1914, as the title indicates is still more limited in its scope; his tentative keys to orders and families published in 1926 provide a reliable means of identifying families on the adult characters.

E g g s: Oviposition may take place on the food-plant, the egg being openly exposed, gummed singly or in clusters, or massed in an ootheca or egg sac; or oviposition occurs in concealment in the food substance or in soil or other form of shelter, the egg being deposited in natural cracks, holes and crevices, or in cavities specially dug or bitten or scraped by female. In the majority of genera a special function of the mouth-parts in oviposition is to assist that of the ovipositor.

L a r v a e: The larvae of primitive families of beetles are either campodeiform with elongate bodies, long legs and anal cerci [see figures of Carabidae], or blattoid, broader in outline, with expanded sides [Lampyridae, Silphidae]. In the decidedly derivative forms the larvae are eruciform, fat, curved grubs; the Lamellicornia have legs and the body is thickened at the anal end [see figures of Scarabaeidae]; some of the eruciform Phytophaga have legs [see figures of Chrysomelidae]; some of the Cerambycidae are without legs, others with very minute legs, or quite distinct legs. [see figures of Cerambycidae]; the larvae of the Rhynchophora are mostly curved legless grubs [see figures of Curculionidae] though most Anthribidae [fig. 6] and some Brenthidae have legs. There is thus a progressive development from the active, armoured, campodeiform type with well developed antennae, mouth-parts and legs as is characteristic of the Adephaga, through the larval forms evolved in the Polyphaga and Lamellicornia, to the climax represented by the soft legless grub with vestigial antennae, reduced mouth-parts and no cerci—"the slothful seed-eating larvae of Rhynchophora" (Leng). The mode of life is the primary modifying factor in the development of larval types; under life-conditions in which the active predatory habit is lost and the larva lives with easy access to its food-supply, modification or degeneration of body-structure is the normal evolutionary course, culminating in the specialised internal-feeding type of larva always surrounded by an abundance of food. Gardner has made a long and regular study of the characters of Indian beetle larvae and has described and figured numerous species in the series "Immature stages of Indian Coleoptera", parts 1-24 published in *Indian Forest Records*, 1925 to date, and in other journals.

P u p a e: The pupae of beetles are soft, pale coloured and the appendages are not fastened to the body. In the Staphylinidae are exceptions, the appendages being covered by a hardened exudation, and in the Coccinellidae the skin is hardened and coloured. Pupation takes place nakedly in the surrounding medium, i.e., soil,

dust, tunnel and the material may be fashioned more or less definitely into a cell or pupal chamber; some groups form cocoons of secretion of carbonate of lime, sericin, etc.

Life-history: In very many, probably the great majority of genera, the food and environment of the imago are different from those of its larva. The imago lives a free active life in the open and the larva lives in concealment or shelter in a different medium. Genera in which the food and environment of the imago are the same as that of its larva are less numerous but are to be found in all categories of food-habits, e.g., (1) herbivorous, all the Platypodidae, *Calopepla* (Chrysomelidae), (2) putrivorous, many Histeridae, Silphidae, (3) carnivorous, many Carabidae, the predacious Coccinellidae.

The life-cycle at its shortest takes about 2 weeks, e.g., *Thea cincta*, (Coccinellidae); 3 to 5 generations a year is not unusual in several groups but an annual basis is the normal for burrowers and borers and predators. The longest life-cycles have been recorded for borers of dry wood—that of *Stromatium barbatum* (Cerambycidae) may last over 10 years (although its normal cycle under favourable conditions is 1 year): longer periods have been recorded for some non-Indian species. Practically all life-cycle periods from the shortest to the annual, are modified in part of the brood by the occurrence of long-cycle individuals which are in most cases larvae.

Emergence-periods in Coleoptera are seasonal and rhythmic in conformity with the period of the life-cycle; in many species the beginning, peak and end of the period are well defined.

CLASSIFICATION OF THE COLEOPTERA

For the classification of the Coleoptera the phylogenetic scheme proposed by Leng is adopted (1920, *Catalogue of the Coleoptera of America, north of Mexico)*. Other classifications with different sequences of families will be found in other literature likely to be consulted by students of forest insects in India, viz.—

Fletcher T.B., 1926, *Agr. Res. Inst., Pusa*, Bull. No. 162, Tentative keys to the orders and families of Indian insects.

Fowler W.W., 1912, *Fauna of British India*, Coleoptera, General introduction.

Lefroy H.M., 1909, *Indian Insect Life.*

Stebbing E.P., 1914, *Indian Forest Insects.* Coleoptera.

Synopsis of the families of the Order COLEOPTERA

Suborder **ADEPHAGA**	
CARABOIDEA	**Cicindelidae**
	Carabidae
	Dytiscidae
GYRINOIDEA	**Gyrinidae**
Suborder **POLYPHAGA**	
HYDROPHILOIDEA	**Hydrophilidae**
SILPHOIDEA	**Silphidae**
	Paussidae
STAPHYLINOIDEA	**Staphylinidae**
	Trichopterygidae
	Histeridae
(**SERRICORNIA** in part)	
CANTHAROIDEA	**Lycidae**
	Lampyridae
	Cantharidae
	Melyridae
	Cleridae
LYMEXYLOIDEA	**Lymexylonidae**
MORDELLOIDEA	**Oedemeridae**
	Mordellidae
	Rhipiphoridae
	Meloidae
	Anthicidae
ELATEROIDEA	**Rhipiceridae**
	Elateridae
	Eucnemidae
	Throscidae
	Buprestidae
BYRRHOIDEA	**Dermestidae**
(**CLAVICORNIA** auct.)	
CUCUJOIDEA	**Ostomidae**
	Nitidulidae
	Cucujidae
	Erotylidae
	Mycetophagidae

	Colydiidae
	Endomychidae
	Coccinellidae
TENEBRIONOIDEA	**Alleculidae**
	Tenebrionidae
	Lagriidae
BOSTRICHOIDEA	**Ptinidae**
	Anobiidae
	Bostrychidae
	Cisidae
(**LAMELLICORNIA** auct.)	
SCARABAEOIDEA	**Scarabaeidae**
	Lucanidae
	Passalidae
(**PHYTOPHAGA** auct.)	
CERAMBYCOIDEA	**Cerambycidae**
	Chrysomelidae
	Bruchidae
(**RHYNCHOPHORA** auct.)	
BRENTOIDEA	**Brenthidae**
CURCULIONOIDEA	**Anthribidae**
	Curculionidae
SCOLYTOIDEA	**Platypodidae**
	Scolytidae

NOTE. The above synopsis omits the names of numerous families and some of the family series used by Leng ; it includes all the family names discussed in this book and places them in the serial order adopted by Leng (except in a few cases of "split" families). The spelling and synonomy of some family names differ from those forms used by Leng ; the forms used in this book are preferred for various reasons.

LITERATURE ON COLEOPTERA :

Beeson C.F.C., 1919-1922, *Ind. For.*, XLV, pp. 49, 139, 312, 488, XLVII, pp. 21, 247, XLVIII, p 494, The food-plants of Indian forest insects.

— 1919, *Ind. For. Rec.*, VII, v, Larvae and life-histories of prionine beetles.

D'Abreu B.A., 1915, *The beetles of the Himalayas*, pp. 70, figs. 47.

Fletcher T B., 1914, *Some South Indian Insects.*

— 1926, *Agr. Res. Inst. Pusa*, Bull. No. 162, Tentative keys to the orders and families of Indian insects.

Fowler W.W., 1912, *Faun. Brit. India*, Coleoptera, General introduction.

Gravely F.H , 1916 *Rec. Ind. Mus.*, XII, pp. 137-175, pls. xx-xii, Some lignicolous beetle larvae from India and Burma.

Lefroy H M , 1909, *Indian Insect Life.*

Stebbing E P., 1914, *Indian Forest Insects of Economic Importance, Coleoptera.*

Gardner, J.C.M , 1925-1938, *Ind. For. Rec* , Ent., XII, old series, to III, new series, Immature stages of Indian Coleoptera Parts 1-24, (References to separate parts are given under families)

ALLECULIDAE

ONLY two species of the small family ALLECULIDAE are of interest, **Cistelomorpha andrewesi** and **C. annuligera**. The beetles, 15-20 mm. long, yellow with black patterning on the elytra, are abundant feeding on the needles and male inflorescences of *Cedrus deodara* and *Pinus excelsa*. Illustrations are given by Stebbing, 1914, *Ind. For. Ins.* p. 244. The larvae are soil-dwellers.

LITERATURE :

Borchmann F., 1915, *Rec. Ind. Mus.*, XI, xi, pp. 179-188, Lagriidae and Alleculidae des Indian Museums.

ANOBIIDAE

VERY few of the Indian ANOBIIDAE have yet been collected and described ; the smaller species are liable to be mistaken for Scolytidae and the larger for Bostrychidae.

The majority of species in the family are wood-borers in the larval stage particularly of dry wood, sticks, climbers, etc., e.g., *Gastrallus birmanicus*, *Ptilinus*, and of woodwork in buildings ; the Death Watch Beetle, *Xestobium rufovillosum*, and the Furniture Beetle, *Anobium punctatum*, are serious pests of wooden roofing, flooring and furniture in Europe, but their corresponding representatives in India are not of much economic importance even in the Himalayas. No Indian species have yet been found attacking cones and twigs of conifers.

A small group comprises species feeding on stored vegetable products, drugs, provisions, etc., e.g., *Lasioderma serricorne*, The Tobacco Beetle, and books and paper records, e.g., *Gastrallus indicus*, The Bookworm.

Some genera breed in fungi particularly the *Polypori* on trees, e.g., *Dorcatoma*, *Macrodorcatoma*, *Stagetomorphus* and *Theca*.

The life-cycle is basically annual with emergence either in the dry hot weather or in the early monsoon, but the maturation of one complete brood may require several years, e.g., *Xestobium* 7 years or *Ptilinus binodulus*, of which some larvae apparently may live for 17 years.

The rate of development of anobiid larvae (*Xestobium*) in wood is dependent on the extent of fungal decay and on the moisture-content ; it is quickest in wood which has lost the highest percentage of weight due to fungus, provided the moisture-content remains high ; hot dry conditions and the absence of decay are unfavourable for quick development.

The larva [fig. 5] feeds on the carbohydrates in wood and is responsible for the reduction of the cellulose-content in which action it may be assisted by micro-organisms (yeast cells in an organ lying anterior to the midgut and connected with it by fine ducts). The chief effect of the wood-rotting fungus appears to be the weakening of the structure of the wood by chemical decomposition so that the

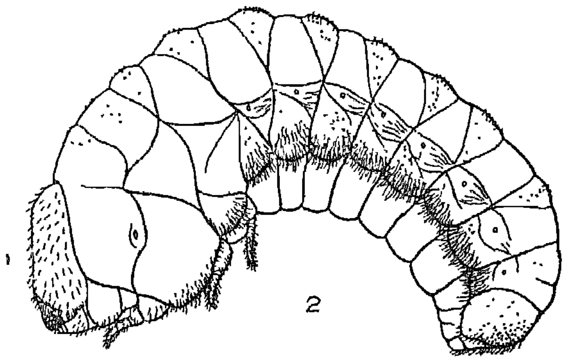

Fig. 5 Larva of Ptilinus pectinicornis, Anobiidae : natural size 6 mm.

larva encounters less resistance in boring ; its predigestive effect, by breaking down the wood components to simpler substances capable of ready assimilation, appears to be less important. Decayed wood forms a higher proportion of the digested food of the larva than does fungus mycelium. (Fisher, 1939).

The larval galleries are circular in cross-section, wholly in the wood and packed with fine wood-dust like that of *Lyctus*, or else coarser and granular. The escape of the beetles produces shotholes of different sizes ; these terminate short lengths of tunnel free from dust.

LITERATURE ON ANOBIIDAE :

Gardner J.C.M., 1937, *Ind. For. Rec.*, Ent., III, No. 6, pp. 129-140, pls. i, ii, Immature stages of Indian Coleoptera (22)

Pic M., 1937, *Ind. For. Rec.*, Ent., III, No. 5, pp. 123-126, Cis Latr. et anobiides nouveaux des Indes.

Garthwaite P.F., 1940, *Guide to the borers of commercial timber in Burma*, pl. vii, fig. 3.

Gastrallus birmanicus is recorded from cordage in Burma.

Gastrallus birmanicus insulcatus in north India breeds in dry sticks and climbers and sometimes in the sapwood of poles and logs. The food-plants are *Acacia gageana, Albizzia lebbek, Artocarpus lakoocha, Bauhinia vahlii, Butea frondosa, Cudrania javanensis, Dalbergia sissoo, Hedera helix, Lannea grandis, Mallotus philippinensis, Mangifera indica, Milletia auriculata, Mucuna imbricata, Ougeinia dalbergioides, Pavetta indica, Pterospermum acerifolium, P. marsupium, Tephrosia candida, Wistaria* sp.

The life-cycle is annual with prolongation up to 4 years ; the emergence-period is extended between April and September in the first year, but the later broods emerge generally in June and July when the atmospheric humidity has risen. Larval tunnels are closely crowded and packed with fine floury wood-dust. The larva is described by Gardner, 1937, *Ind. For. Rec.*, Ent., III, No. 6, p. 134, figs. 13-20.

Gastrallus indicus. This species is the "Bookworm" in India and Burma and is responsible for the perforations and tunnels in the covers, books, printed records and files of many libraries and record offices. True bookworm damage is distinguished from that of other pests of libraries by the presence of circular pinholes or shotholes and empty parallel-sided tunnels which are mainly concentrated in the boards and bindings for the sake of the paste and glue; perforations made by escaping beetles also run straight through a book from one side to the other.

It has previously been referred to erroneously as *Sitodrepa panicea*.

For control see Part Two, Anobiidae. Larval characters are given by Gardner, 1937, *Ind. For. Rec.*, Ent., III, No. 6, p. 135.

Gastrallus laticollis is the Bookworm of the Netherlands Indies (Kalshoven, 1938).

Gastrallus plicaticollis occurs in south India and breeds in dry sticks, including twigs of *Acacia* and *Albizzia*. Emergence in April, May with an annual life-cycle.

Lasioderma serricorne, the Tobacco Beetle, is a serious pest in cigar and cigarette factories everywhere. The beetle attacks the tobacco leaf soon after it has been harvested and before it is baled and the pest is carried over in the manufacture of the cigars as its larval period requires 150-170 days. It also breeds in opium cakes, turmeric, etc., herbarium specimens and in seeds, e.g., asters, *Tectona grandis*, and in roots, e.g., *Cucuma longa;* it has also been reared from wood attacked by borers. The life-cycle is normally annual but infested material may yield beetles for 2 years. A full plate showing the stages in the life-history is given by Lefroy and Fletcher.

LITERATURE:

Gardner, J.C.M., 1936, *Ind. For. Rec.* Ent., III, No. 6, pp. 135, 136 (larva).
Mackie D.B., 1916, *Trop. Agric.*, XLVI, pp. 170, 171.
— 1915, *tit cit*, p. 248
Runner G.A., 1918, *Trop. Agric.*, XLVIII, pp. 104-106.

Priobium luteopilosum breeds in the wood of *Quercus* sp. and possibly *Cedrus deodara*. The larva is described by Gardner, 1937, *Ind. For. Rec.*, Ent., III, No. 6, pp. 133, 134, figs. 8-12.

Ptilinus binodulus occurs throughout India and Ceylon in the wood of *Boswellia serrata, Canarium euphyllum, Ficus roxburghii, Grevillea robusta, Morus alba, M. laevigata, Parishia insignis, Quercus incana, Q. serrata, Semecarpus anacardium, Spatholobus roxburghii, Sterculia campanulata, Vateria indica.*

The life-cycle is on an annual basis but under adverse conditions may be prolonged for several years. The longest insectary record is 17 years in logs of *Quercus incana* (Dehra Dun) from which beetles emerged year after year regularly in April-June, mainly in the hot dry weather of May. It is probable that fresh oviposition by beetles before swarming took place in some years, but it is possible that some life-cycles lasted 17 years. The larva

is described by Gardner, 1937, *Ind. For. Rec.*, Ent., II, No. 6, p. 133, figs. 5, 7. The larval gallery is circular in cross-section and the dust is fine and floury.

Ptilinus pectinicornis, a European species, occurs in the Himalayas in *Acer caesium*, *Quercus dilatata*, *Q. incana*, *Q. semecarpifolia*. Beetles are in the wood in May, June. Escherisch states that the beetles pass the greater part of their lives in the tunnels and do not leave them for pairing. The eggs are laid in the tunnel so that the whole life-cycle is completed in the shelter of the wood. The larva [fig. 5] is described by Gardner, 1937, *tit. cit.*, pp. 132, 133, figs. 1-5. The dust in the larval tunnel is fine and powdery like that of *Lyctus*.

Ptilinus sulcatus in *Prunus armeniaca*.

Ptilineurus elegans in *Kydia calycina*. Emergence in April.

Sitodrepa panicea is a cosmopolitan pest of stored vegetable products including drugs, seeds, flour, biscuits, etc.; it is also recorded as a "bookworm". At Dehra Dun it flourished for 6 years in aster seeds, beetles emerging in all months of the year.

ANTHICIDAE

Many species of small antlike beetles of the family ANTHICIDAE are found on foliage of trees; twenty species were collected on the foliage of sandal, *Santalum album*, in the insect survey of that tree in North Salem, Madras and Coorg. The commonest species were **Formicomus sulcipes** and **F. maindroni**. The larvae occur in soil and among dead fallen leaves where they are supposed to be predaceous on smaller organisms in the soil; pupation occurs in the soil. Figures of all stages of **Formicomus caeruleipennis** are given in *Agr. Res. Inst., Pusa*, Bull. No. 89 (1919), p. 24. fig. 16.

LITERATURE ON ANTHICIDAE:

Heberdy R. F., 1934, *Ind. For. Rec.*, XX, vi, pp. 1-14, pl. 1, figs. 9, Entomological investigations on the spike disease of sandal. (23) Anthicidae.

ANTHRIBIDAE

A comparatively small family of the Rhynchophora. With the exception of a few species all ANTHRIBIDAE are borers of dead or rotten wood in the larval stages. Some species of the genera *Araecerus* and *Zygaenodes* are seed and fruit borers, and some *Anthribus* and *Brachytarsus* (not known in India) are predacious on Coccidae.

The egg is laid by the female in a pit gnawed by the mandibles in bark or epidermis. The larval tunnel is either mainly in the bark, or grooves the surface of the sapwood more deeply, or is wholly within the sapwood. In some genera, e.g., *Phloeobius* the larval tunnels run more or less parallel with the axis of the stem and just within the outer zone of sapwood and often when crowded are confluent; they are filled with a fine wood-dust that is

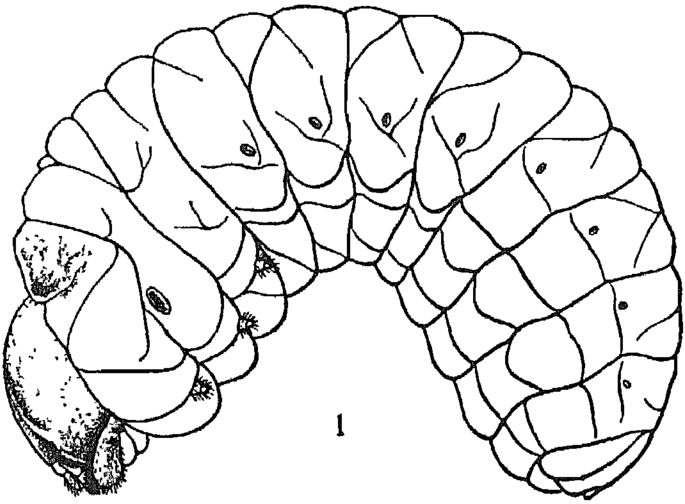

Fig. 6. **Larva** of Meganthribus tessellatus. Anthribidae : natural size 36 mm.

not so floury as that produced by bostrychid larvae. The wood-feeding larvae [see fig. 6] appear to be associated with cellulose-destroying fungi but the true source of their food is unknown. In any case the presence of buccal molar parts suggests that grinding is a necessary pre-digestive process. In one genus *Autotropis* the hypopharyngeal sclerome is absent but the stomodeum is modified into a structure that probably compensates for the absence of the buccal grinding apparatus (Gardner, 1936).

The pupal cell is orientated parallel to the long axis of the stem and is connected to the exit-hole by a short tunnel joining it in a curve or a right angle. Soft felted fibres form a lining to the cell; the lining is in some species stained black.

The life-cycle in the majority of the wood-borers is annual with the beetles emerging towards the end of the hot weather or in the monsoon, and the emergence-period is often prolonged; in some species (e.g., *Tropideres*, *Ozotomerus*, *Basitropis)* two generations a year are possible, beetles maturing in the post-monsoon season from eggs laid in the spring.

In the seed and fruit-boring group the life-cycle is short and six or more generations may follow in a year, the rate of development being affected considerably by humidity (Van der Goot, 1917 and Taher el Sayed, 1935).

The adults are long-lived. Wood-boring species often collect in large numbers on felled and fallen logs or frequent foilage. In the entomological survey of the fauna of sandal, *Santalum album*, in south India 17 species of Anthribidae were taken on the foliage

of that tree, but none of them feeds on it. Species were most numerous in January (10) and in June (12). Adults of *Phloeobius brevitarsus* and *Zygaenodes horni* occurred all the year round and adults of several other species were active for 6-8 months. In the north during the cold season adults are found sheltering in bark.

Practically all the recently discovered species of Indian Anthribidae have been described by K. Jordan in *Novitates Zoologicae* and a few in the papers listed below. The larvae have been described by Gardner.

LITERATURE ON ANTHRIBIDAE :

Gardner J.C.M., 1932, *Ind. For. Rec.*, Ent., XVI, xi, pp. 327-334, pl. 1, Immature stages of Indian Coleoptera (10)

— 1936, *tit cit.*, new series. Ent., II, No. 2, pp. 99-112, pl. i, ii. ibid. (19).

— 1937, *tit cit.*, III, No. 6, pp. 127-138. pl. ii. ibid. (22).

Jordan K., 1913, *Rec. Ind. Mus.*, VIII, pp. 197, 203-216, Anthribidae of the Arbor expedition.

— 1933, *Ind. For. Rec.*, Ent., XVIII, iii, pp. 1-8, Entomological investigations of the spike disease of sandal (6), Anthribidae.

Van der Goot P., 1917, *Meded v. h. Proefst. Mid. Java*, No. 26, pp. 1-36, pls. 2, Het Tephrosia-Kevertje.

Acorynus carinifrons bores the wood of *Anthocephalus cadamba* and *Quercus spicata*. Emergence in April, May and September. The larva is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 2, p. 107, figs. 24, 25.

Acorynus laenatus in *Albizzia lebbek*. Emergence in September.

Androceras khasianus in *Terminalia myriocarpa*. Emergence in May, June and September. The larva is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 2, pp. 103, 104, figs. 13, 14.

Androceras pulcherrimus in *Alnus nepalensis*. Emergence in April.

Araecerus candicans in *Terminalia procera* wood. Emergence in May.

Araecerus fasciculatus breeds in various seeds of trees and shrubs and readily in the pods and seeds of Papilionaceae. It is of considerable importance as a pest of stored products and is now cosmopolitan.

Among the foodplants are *Anona squamosa*, *Areca catechu*, *Artocarpus hirsuta*, *Cassia occidentalis*, *Crotolaria striata*, *Indigofera* sp., *Leucaena glauca*, *Melanorrhoea usitata*, *Pentacme suavis*, *Tephrosia candida*, *Terminalia catappa*. It is particularly a pest of *Tephrosia candida* (Van der Goot, 1917).

The beetle is 4 to 4.5 mm. long. Eggs are laid on the ripe pods or fruits which are fresh and moist. Holes are gnawed and a single egg is deposited in each hole close to a seed. Hatching occurs in about a week and the larva bores into the seed and later into adjacent seeds in a pod and is full grown in about 4 weeks. The pupal period lasts for a week or ten days and the immature adult remains for some time within the pod or fruit before emerging. The beetles pair after a few days and the female begins at once to oviposit in available young or old pods. In stored seeds

it is thus possible for breeding to be practically continuous and for 6 or 7 generations to be completed in one year. According to Taher el Sayed (1935) the life-cycle varies from 30 days at 100 percent humidity to 70 days at 60 percent. The following figures show the number of beetles of *A. fasciculatus* maturing each month in an infestation of seeds of *Melanorrhoea usitata* from Burma :—

Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.
41	82	66	101	61	28	23	162	435	306	32	3

The population is thus greatest in May, June. The beetles live for one to three months at relative humidities above 50 percent. When seeds are not available the beetles shelter in bark or vegetable matter ; they are capable of flying long distances. The larva is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 2 p. 100.

LITERATURE :

Goot Van der, P., 1917, *Meded, v. h. Proefst. Mid. Java*, No. 26, pp.1-36, pls. 2, Het Tephrosia-Kevertje.

Petch T., 1929, *Tea Quarterly*, II, p. 22. Combating the Tephrosia weevil.

Hutson J. C., 1932, *Trop. Agric.*, LXXVIII, p. 140. Insect pests of green manuring.

Araecerus intangens breeds in fruits of *Jatropha curcas* and *Punica granatum*, emerging in March and September.

Araecerus simulatus breeds in the seeds of *Dalbergia fusca* and is adult in March, April.

Araecerus suturalis breeds in the fruits of *Acacia arabica*, *Aleurites fordii*, *Ficus glomerata*, *Jatropha curcas*, *Melia indica*, *Trachycarpus excelsa* and in dead buds of *Mangifera indica*, and dry papaya stem. Emergence occurs in all months from March to December but mainly in the spring and autumn in India. The larva is described by Gardner, 1932, *Ind. For. Rec.*, Ent., XVI, xi, p. 328, pl. I, figs. 1-5.

Autotropis modesta conspersa breeds in dry sticks of *Acrocarpus fraxinifolius*, *Albizzia* sp., *Tamarindus indica*, *Tephrosia candida*, and an unidentified creeper. The overwintered generation emerges in April. The larva is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 2, pp. 102-103, figs. 26-28.

Autotropis notatus in *Acrocarpus fraxinifolius*. Emergence in May.

Basitropis affinis in *Chloroxylon swietenia*. Emergence in May.

Basitropis hamata in wood of *Bombax malabaricum*, *Butea frondosa*, *Ficus rumphii*, *Garuga pinnata*, *Lagerstroemia parviflora*, *Lannea grandis*, *Pongamia glabra*, *Spondias mangifera* and *Zizyphus xylopyra*. The larva is described by Gardner, 1937, *Ind. For. Rec.*, Ent., III, No. 6, pp. 127, 128, figs. 33, 34. The generation is apparently annual with emergence in June, July.

Basitropis nitidicutis bores the wood of *Artocarpus lakoocha*, *Dalbergia paniculata*, *Eugenia jambolana*, *Ficus asperrima*,

F. hispida, *F. infectoria*, *Heritiera fomes*, *Mangifera indica*, *Pongamia glabra*, *Shorea robusta*, and *Spondias mangifera*. Emergence occurs in April–August but mainly in May; in north-east India a portion of the annual generation may consist of short-cycle larvae maturing in October.

Basitropis rotundata in *Lannea grandis*.

Caranistes arboreus and **C. variegatus** were bred from stems of saplings of *Terminalia arjuna* received in Dehra Dun from Mauritius. Emergence in April. The larva of *C. variegatus* is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II. No. 2, p. 111, figs. 29-31.

Dendrotogus angustipennis in *Dichopsis polyantha*, *Eugenia jambolana*, *Lannea grandis*, *Machilus odoratissima*, *Shorea assamica*, *Shorea robusta*, *Sonneratia apetala*, *Stephygyne parvifolia*.

Dendrotrogus colligens in *Chloroxylon swietenia*, *Shorea robusta*, *S. tumbuggiana*, *Terminalia chebula*, *Vitex pinnata*. Emergence occurs from December–August. The larva is described by Gardner, 1936, *Ind. For. Rec.*, II, No. 2. p. 104, figs. 7-9.

Dendrotrogus perfolicornis in *Acrocarpus fraxinifolius*, *Chikrassia tabularis*, *Terminalia pyrifolia*. Emergence in April, May. The larva is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II. No. 2, p. 104.

Deropygus chaerilus in *Kydia calycina*. Emergence in April.

Disphaeroma verrucosa in *Acacia melanoxylon*.

Eucorynus crassicornis in *Albizzia lebbek*, *Ailanthus malabarica*, *Artocarpus lakoocha*, *Buchanania latifolia*, *Euphorbia pulcherrima*, *Ficus carica*, *F. bengalensis*, *Garuga pinnata*, *Lannea grandis*, *Mallotus philippinensis*, *Manihot glaziovii*, *Milletia auriculata*, *Pavetta indica*, *Quercus serrata*, *Ricinus communis*, *Sarcocephalus cordata*, *Semecarpus anacardium*, *Shorea robusta*, *Spondias mangifera*, *Terminalia tomentosa*.

The pupal chamber is horizontal at right angles to the surface of the sapwood. Emergence occurs throughout the year from February to November according to the time of oviposition but the life-cycle is normally annual with the greatest adult population in April, May and in September, October. The larva is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 2, p. 105, figs. 22, 23.

Exillis asper in *Euphorbia pulcherrima*, *Girardinia heterophylla*, *Lannea grandis*, *Michelia champaca*. Emergence in August, September; generation is annual.

Gibber callistus in *Ficus religiosa*, *Mezenga xanthoxylum*, *Michelia champaca*. The emergence-period is prolonged from July onwards upto January; the generation is annual with long-cycle larvae. The larva is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 2, p. 108.

Gibber frenatus in *Albizzia* sp., *Dalbergia sissoo*, *Gerardinia*

heterophylla, Mezenga xanthoxylum. Emergence occurs in September November.

Habrissus sellifer in *Erythrina indica.* Emergence in August.

Hucus bicolor numatus in *Croton oblongifolium* and *Erythrina* sp.

Hucus loratus in *Polyalthia simiarum.* Emergence in September.

Litocerus crucicollis in *Pterocarpus marsupium.* Emergence in September, November; beetles occur in May.

Litocerus khasianus in *Juglans regia.* Emergence in March, April.

Meganthribus tessellatus in *Macaranga denticulata.* Emergence in May. The larva is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II. No. 2, p. 109, figs. 1-6. [see fig. 6.]

Melanopsacus anthracinus in *Shorea robusta.* Emergence in May, June.

Melanopsacus nanellus in *Michelia champaca.* Emergence in July, August.

Merarius glabriceps in *Mallotus roxburghianus.*

Misthosima separ in *Michelia champaca.* Emergence in August.

Nessiodocus celsus in *Hopea wightiana.* Emergence in June.

Ozotomerus maculosus in the sapwood of *Acrocarpus fraxinifolius, Heritiera fomes, Hopea odorata, Mangifera indica, Mimusops littoralis, Shorea robusta.* Emergence occurs from April to September; the overwintering generation produces beetles in the hot weather and these may complete a second generation by the end of the monsoon or in the following spring. The larva is described by Gardner, 1936, *Ind. For. Rec.* Ent., II, No 2, p 110.

Phaeochrotes cinereomaculata in *Cinnamomum cecidodaphne, Ficus religiosa, Mangifera indica.* Emergence in April, May and August.

Phaeochrotes porcellus in *Sideroxylon longipetiolatum.* Emergence in April.

Phaulimia caena in *Calophyllum walkeri, Dipterocarpus zeylanicus* and *Gordonia zeylanica.* Emergence in April, May.

Phloeobius alternans in dry *Bambusa polymorpha, Erythrina lithosperma* and *Xylia dolabriformis.* The beetle occurs in July, November.

Phloeobius crassicollis in dry solid *Dendrocalamus strictus.* The tunnels are confluent and packed with fairly fine wood-dust; the pupal chamber is lined with smooth felt and is connected with a short transverse tunnel to the circular exit-hole. Emergence occurs in May-July, mainly May.

Phloeobius gigas in *Kydia calycina.* Emergence occurs in May, June.

Phloeobius lutosus in dry *Dendrocalamus strictus.*

Phloeobius pilipes in *Gmelina arborea, Lagerstroemia flosreginae.* The galleries run irregularly in the inner surface of the

bark and about 2/3rds deep in the sapwood, in cross-section roughly circular, filled with fine wood-dust (but not as floury as that of Bostrychidae). They may be tunnelled below the surface of the sapwood to about 1/2 an inch deep. The pupal chamber lies vertically, is oval and lined with a finely felted blackened layer of wood-fibres; the emergence-hole is circular. Emergence in June. The larva is described by Gardner, 1932, *Ind. For. Rec.*, Ent., XVI, xi, pp. 329, 330, pl. I, figs. 6-11.

Physopterus agrestis in *Shorea robusta.* Beetles occur under bark in November–February and on the wing in June.

Rawasia ritsemae in dry *Bambusa polymorpha.* Emergence in April, May.

Rhaphitropis carbo in *Bombax malabaricum, Broussonetia papyrifera, Dalbergia latifolia, Euphorbia pulcherrima.* Emergence in May, June.

Rhaphitropis cosmia in *Michelia champaca.* Emergence in August.

Rhaphitropis incanus in *Dalbergia latifolia, Michelia champaca, Morus indica.* Emergence in July, August.

Rhaphitropus indicus and **R. stevensi** in *Acacia gageana.* Emergence in September.

Stiboderes impressus in *Phoebe lanceolata.* The larva is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 2, figs. 10-12.

Tropideres bolinus in the sapwood of *Artocarpus hirsuta, Gmelina arborea, Mallotus philippinensis, Quercus incana, Shorea robusta, Terminalia tomentosa.* There are two generations a year, the beetles of the first emerging in August–December but preponderantly in September, October. The eggs laid by this generation give rise to beetles in March, April or in the monsoon, i.e., short and long cycled larvae. The adults live for some months and attack logs a month or more after felling but not freshly felled material.

Tropideres labidus in *Heritiera fomes, Tectona grandis, Terminalia tomentosa.* Emergence in March, April and August–October.

Tropideres luteago in *Albizzia* sp., *Girardinia heterophylla, Michelia champaca, Tectona grandis.* Emergence in July–September. The larva is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 2, p. 106, figs. 18-20.

Tropideres munieri in *Populus euphratica.*

Tropideres notabilis in *Dolichandrone rheedii, Millettia pendula, Terminalia belerica.* Emergence in October, November.

Tropideres paviei in *Ailanthus malabaricus, Bombax malabaricum, Butea superba, Dalbergia latifolia, Millettia* sp., *Shorea robusta.* Emergence in April and September; beetles occur in bark during the cold months.

Tropideres securus in dry sticks as well as logs of *Albizzia* sp.,

Dalbergia sissoo, Euphorbia pulcherrima, Lannea grandis, Quercus incana, Shorea assamica, S. robusta, Terminalia tomentosa. Emergence occurs from May to October. The larva is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 2, p. 106.

Tropideres vigens in *Juglans regia.*

Ulorhinus brachystomus in *Erythrina indica.* Emergence in August.

Uncifer ? alienus in *Acacia gageana, Ficus glomerata, Ougeinia dalbergioides.* Emergence in July–September.

Uncifer myodes in *Michelia champaca.* Emergence in August.

Uncifer stigmosus in *Artocarpus lakoocha, Mangifera indica.* Emergence in May–August. The larva is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 2, p. 108, fig. 21.

Xenocerus khasianus in *Mesua ferrea.*

Xenocerus rectilineatus in *Artocarpus lakoocha, Buchanania latifolia, Dalbergia paniculata, Pterocarpus marsupium.* Emergence in May -July.

Xylinades andamanensis in *Myristica andamanica.* Emergence in May. The larva is described by Gardner, 1932, *Ind. For. Rec.*, Ent., XVI, xi, pp. 332, 333, pl. i figs. 19-21.

Xylinades beesoni in *Pterocarpus marsupium.* Emergence in July.

Xylinades plagiatus in *Dalbergia sissoo, Lannea grandis, Shorea robusta, Xylia dolabriformis.* Emergence occurs in April, May. The pupal chamber runs in horizontally at right angles to the surface of the sapwood.

Zygaenodes ferrealis breeds in seeds of *Mesua ferrea.*

Zygaenodes ? molitor in *Gmelina arborea, Michelia champaca.* Emergence in April and July.

Zygaenodes triangularis in *Bombax malabaricum* and *Pinus longifolia.*

BOSTRYCHIDAE

RELATIVELY more is known of the food-plants of the family BOSTRYCHIDAE than of any other family of beetles in the Oriental Region. Only 87 species of Bostrychidae occur in India, Burma and Ceylon but food-plants are known for 70 of these species; they include over 250 species of trees, woody shrubs and climbers. Following the authority of Lesne, the Lyctinae or 'Lyctus Beetles' are included in this family and the whole group is known popularly as 'Powder-post Beetles'. Small as the family is, it is of great economic importance to forestry and the wood-using industries, because of the damage done to manufactured softwood and sapwood articles, furniture, plywood, matches and matchboxes, packing-case boards and shooks, tent-poles and tent-pins, lance staves and lathis, tool-handles and sports goods, etc. Ecologically the species can be assigned to the following groups:

i. The cylindrical Powder-post Beetles, *Heterobostrychus*, *Sinoxylon*, *Schistoceros*, *Xylodectes*.
ii. The flattened Powder-post Beetles, *Lyctus*, *Minthea*, *Trogoxylon*.
iii. The bamboo borers, or ghoon, *Dinoderus*.
iv. Pests of flour, and other stored food substances, *Rhizopertha*.
v. Commensals, *Lyctoderma*, *Lyctoxylon*.

System of tunnels: All the wood-boring groups have one common characteristic: the larva bores a tunnel in starchy wood (including bamboo, cane, palm), the tunnel being circular in cross-section and packed densely with a very fine floury wood-dust. A heavy infestation of closely crowded larval tunnels reduces the wood to powder: hence the name Powder-post Beetles. The floury dust and the circular bore of the tunnel distinguish the work of Bostrychidae from other families of wood-borers, e.g., Buprestidae, Cerambycidae.

In groups i and iii, the cylindrical beetles, the female bores a tunnel through the bark into the wood, where it turns and runs in a transverse plane parallel to the circumference, sometimes for several inches; eggs are laid in pores or in niches on the walls of this sapwood tunnel. In group ii, the Lyctus beetles, the female does not bore into the wood but lays an egg inside a cut and exposed wood-vessel on the outer surface; consequently the food-plant can be attacked only after it has been broken, or cut, or perforated by other borers. In groups i, ii and iii the larval tunnel is excavated with the grain, i.e., following the length of the wood vessels upwards or downwards from the site of the egg, and its diameter increases as the larva grows in size; only in crowded populations is the larval tunnel forced to follow an irregular or reversed course. Pupation occurs at the extremities of the larval tunnel and the beetle bores out by the shortest route to the surface.

Larvae: Bostrychid larvae have a curved body enlarged at the thorax with well developed legs, annular spiracles and gouge-shaped mandibles. Descriptions and classification of numerous species of Indian bostrychid larvae are given by Gardner (1933). Larval characters indicate that the Lyctidae should be maintained as a distinct family. Anderson (1939.)

Collections and new species from the Indian region have been identified and described by P. Lesne; there are no taxonomic papers and no modern catalogue of Indian species in Indian journals except as listed below, but there are numerous monographs by Lesne in foreign literature.

Food: Bostrychidae are essentially polyphagous; it is exceptional for the food-plants of one species to be restricted to one genus or one generic group of plants.

Over 120 food-plants are known for *Minthea rugicollis* in the

Indo Malayan Region. The most polyphagous Indian bostrychid is *Lyctus africanus* for which 90 food-plants are recorded. The trees attacked by the largest number of species of Bostrychidae are *Shorea robusta*, *Mallotus philippinensis* and *Mangifera indica* from which 26, 27 and 28 species of Bostrychidae are recorded respectively.

Starch is an essential constituent of the food of *Dinoderus*, *Heterobostrychus*, *Rhizopertha*, *Sinoxylon* and Lyctinae, if not of all Bostrychidae.

Life-cycle: Many species have annual generations; three generations is normal in several groups and four generations a year is the highest number recorded for any species.

All species exhibit as a normal characteristic delayed development of part of a brood, the period of delay amounting to one or more cycles of average length, e.g., some of the brood of a species with an annual generation may not mature until the second or third year, and a species with a normal life cycle of three months may not mature for six or nine months (according to whether or not the hibernation diapause intervenes). The factors responsible for delayed development are competition for food in crowded infestations, and variation in the moisture-content of the wood (due to the rate of loss of moisture, and the seasonal reabsorption of moisture).

Emergence-period: Adult beetles remain in the wood without emerging for periods that vary over a wide range; some species pair and oviposit in the wood in which they fed as larvae. Adults of some species live for several months.

The majority of species of wood-borers emerge most abundantly at periods in the spring, summer and autumn, and are inactive in the winter; whereas several species of Lyctinae emerge most abundantly in the autumn and cold season. It is possible that the latter were originally temperate region species, but being now distributed by commerce in tropical and subtropical regions have acquired a diapause which operates at temperatures higher than the maxima of summer in temperate regions. The micro-climate of the habitat of a bostrychid larva or immature beetle is that of the wood in which it develops, and differs very considerably from that of the flying adult beetle. And both habitats vary from the shelter of the interior of a building to the exposed conditions of open air.

For control of powder-post beetles and Lyctus beetles see Part Two, Bostrychidae.

LITERATURE ON BOSTRYCHIDAE:

Atkinson D.S., 1933, *Ind. For.*, pp. 226-232.

— 1936, *Burma For. Bull.*, No. 32.

Beeson, 1919, *Ind. For.*, XLV, pp. 49-56, The food-plants of Indian forest insects.

— 1924, *Proc. 5th Ent. Meet., Pusa.* pp. 159-175, The geographical distribution of the coleopterous borers of Shorea robusta.

— 1933, *Ind. For.*, LIX,, pp. 158-164, Lyctus beetles in India.

— 1933, *Ind. For.*, LIX, pp 709-712. The liability of solid bamboo lance staves to attack by borers.
— 1933, *Ind. For. Rec.*, XVIII, IX, pp. 1-12, Entomological investigations on the spike disease of Sandal (2), Bostrychidae, Platypodidae and Scolytidae.
— 1935, *Ind. For.*, LXI, pp. 250-255, Boxwood borers (Heterobostrychus).
Beeson and Bhatia B.M., 1937, *Ind. For. Rec*, Ent., II, No. 12, pp. 223-320, figs. pls., On the biology of the Bostrychidae (also list of species)
Gardner J.C.M., 1933, *Ind. For. Rec*, Ent., XVIII, xi, pp. 1-19, pls, Immature stages of Indian Coleoptera (13), Bostrychidae.

Apate submedia in *Casuarina equisetifolia.*

Apoleon edax in *Dipterocarpus tuberculatus* and *turbinatus*. Recorded as damaging bungalow posts and rigs of oil derricks of *in* (*Dipterocarpus tuberculatus*) in company with *Sinoxylon crassum* in Burma (Katha). The larva is described and figured by Gardner, 1933, *Ind. For. Rec.*, XVIII, ix, p. 3, pl. 1, figs. 1-6.

Bostrychopsis bengalensis in *Dendrocalamus strictus* and as a borer of wooden tent-poles and tent-pegs in military arsenals. The life-cycle is annual with emergence in June, July. Occurs throughout India and in Burma.

Bostrychopsis parallela in *Bambusa arundinacea, Boswellia serrata, Dendrocalamus strictus, Mallotus philippinensis, Mangifera indica, Pterocarpus indicus, Smilax* sp. Widely distributed in the Oriental Region.

This species is primarily a borer of dry bamboos, especially of the larger dimensions used for tent-poles and army telegraph-poles. The life-cycle in *Dendrocalamus strictus* is normally annual but is frequently prolonged for two or three years. The longest recorded cycle is six years in bamboo tent-poles stored in a military arsenal. The main emergence-period is between the beginning of June and the end of September with 40 percent of the annual population emerging in July; about 10 percent of beetles mature during the remaining periods of the year, Snyder (1927) gives an illustration of duali plywood from the Philippines with tunnels of *B. parallela* in the thick middle core. The beetle varies in length from 9 to 14 mm. The larva is about 10 mm. long when mature and is described and figured by Gardner (1933, *Ind. For. Rec.* XVIII, IX, p. 14, pl. iv, figs. 50, 51).

Calopertha truncatula in *Acacia albida, Acacia modesta.* A north African species extending to northwest India.

The genus Dinoderus

LIFE-HISTORY OF SPECIES OF DINODERUS ATTACKING BAMBOO.

(See also under *brevis, minutus* and *occelaris*, postea).

The borers of felled bamboo known as '*ghoon*' or 'shotborer' or 'shothole borer'* are three species of *Dinoderus* —*brevis,*

*This term "shothole borer" is better restricted to ambrosia beetles, i.e., Scolytidae and Platypodidae.

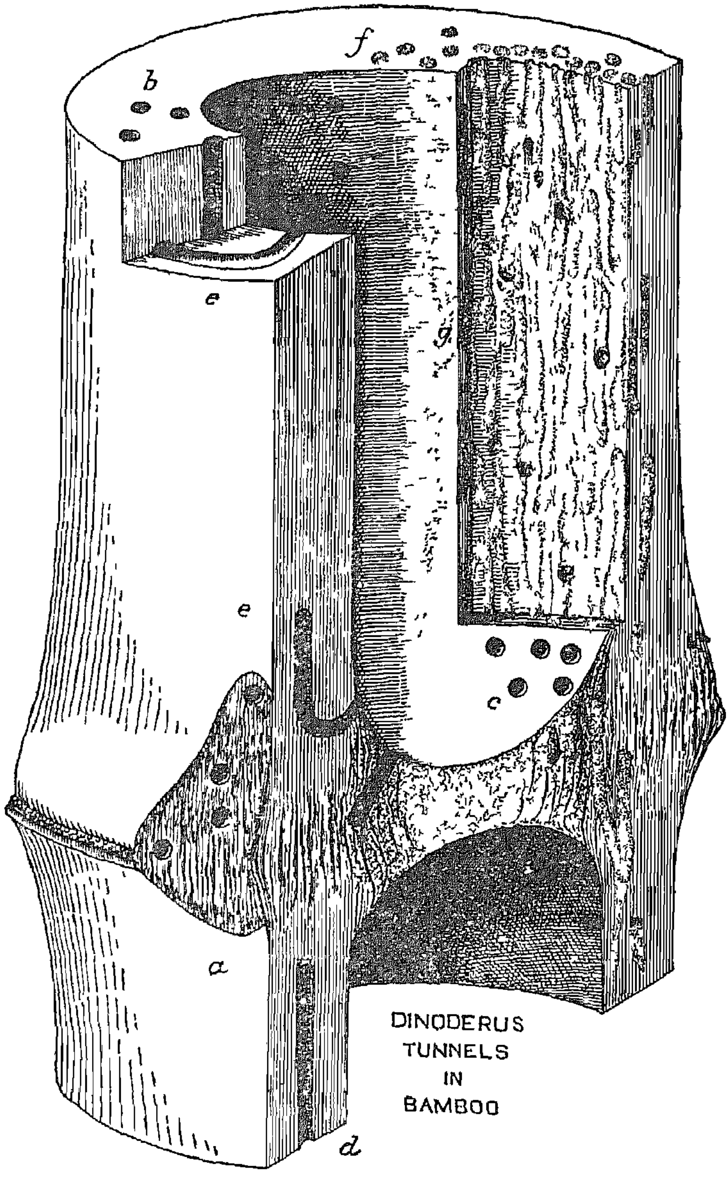

Fig 7. Bamboo (*Dendrocalamus strictus*) showing attack of *Dinoderus* spp (Ghoon).

(*For explanation see bottom of page 55*)

minutus and *ocellaris*. As their habits are similar, a general account will suffice to describe the life-histories of all three.

Site of entrance-hole: The beetle bores into the cut bamboo at a spot where the external rind has been severed or removed, e.g., by trimming off the side branches, or smoothing nodes, by splits or abrasions [see fig. 7 (*a*)]; it also bores into the exposed transverse sections of cut ends [fig. 7 (*b*)] and into the internal walls of the terminal internodes of hollow bamboos [fig. 7 (*c*)], It is very difficult, if not impossible, for the beetle to bore through the hard external rind unless it can get a foothold on an adjacent surface at an angle to the attacked surface. A suitable initial purchase is formed by two bamboos in contact as when bundled or stacked lengthways, but such spots are avoided by the beetle if it can find easier places of entry. Holes made by the earliest arriving beetles are largely used by subsequent arrivals.

The entrance-tunnel is carried in for a fraction of an inch towards the centre in a solid culm and between the walls [fig. 7 (*d*)] in a hollow culm, or axially with the grain if started at a cut end and is often expanded into a chamber for turning about. It may be continued vertically or horizontally to form an oviposition tunnel [fig. 7 (*e*)]. The dust derived from the construction of the tunnel is all ejected. Pairing takes place inside the tunnel and eggs are laid in such pores as are exposed in the walls.

Larval tunnel: Each larva bores a tunnel upwards or downwards coaxially with the fibres. In a crowded infestation the course of the tunnel is very irregular, crossing other tunnels and reversing its direction. In a hollow bamboo the larval tunnels tend to be concentrated in the innermost zone of the internodal wall avoiding the outer zone where the fibrovascular tissue is dense

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Fig. 7. Dinoderus tunnels in Bamboo.

Dendrocalamus strictus showing attack of *Dinoderus* spp. (Ghoon).

(*a*) Entrance holes bored by the beetles into the surface exposed by cutting off side-shoots.
(*b*) Entrance holes bored by the beetles in the exposed transverse section of cut ends.
(*c*) Entrance holes in the internal wall of the internode which has been rendered accessible to the beetles by cutting across the bamboo before the next node.
(*d*) Entrance tunnels carried in the wall from the cut end.
(*e*) Entrance tunnels in vertical and horizontal sections (exposed diagramatically).
(*f*) Larval tunnels exposed diagramatically in transverse section.
(*g*) Larval tunnels exposed diagramatically in tangential section after removing the inner wall.

and nutritious parenchyma is scarce or absent. [fig. 7 *(f)*]. The tunnel is tightly packed with a finely comminuted frass that is not a floury powder like that of *Lyctus*, but consists mainly of coarser though very minute particles of woody tissue which have not lost their cellular structure. The particles in the tunnel of the younger larva are smaller than those in the tunnel of an older larva. It is presumed that the larva tears off the small particles of tissue and tastes them, rejecting the horny fibres as relatively long fragments of the latter occur in the frass and the very young larva avoids boring in the bundles of fibres (sclerenchymatous cells). The palatable parenchyma is chewed into fragments much smaller than could be gripped by the tearing or chiselling action of the mandibles. The whole of this chewed material is presumably ingested and is passed through the alimentary canal without visible change other than the loss of starch grains. Staining a section of bamboo containing a larval tunnel shows up the starch-filled parenchyma in black, but the colour of the larval frass remains unchanged. A few particles of starch may occur in it either as loose grains or in rare pieces of uneaten parenchyma but, relatively, the frass is devoid of starch. The larval frass is practically formless, with no indication of faecal pellets.

Fig. 7 at *(g)* shows the appearance of crowded larval tunnels after removing a strip of the inner wall of a hollow bamboo. Although the epidermis of the inside of a hollow internode is soft and fragile it is not destroyed until the whole of the woody tissue has been reduced to dust.

Pupation: The number of larval instars has not been determined; there are at least three and probably four. The moulted larval exuviae are buried in the subsequent frass. Pupation occurs in a cell at the end of the larval tunnel and the pupal stage is of very short duration. The immature beetle spends a variable amount of time in further feeding before escaping; it may bore out through the rind immediately above its pupal cell or may cover long distances and eventually emerge by one of the original entrance holes. The frass of the immature beetle is coarser than that of the larva and its excrement is in the form of spherical pellets.

Second generation: After emergence the beetle may fly away or may explore the same piece of bamboo entering preformed holes and tunnels for further feeding and eventual pairing, and to deposit the eggs of the next generation. The larvae of subsequent generations work in the frass of previous tunnels and in the unattacked wood until the whole culm is reduced to dust. In a hollow bamboo the cavity of the internode may be filled with dust ejected through holes in the inner wall. The outer rind is able to hold the whole together until there are as many as 800 holes in a one foot length of an inch or two in diameter.

The longest period of infestation of a bamboo that we have re-

corded is five years. This was an I. P. tent pole from Rawalpindi Arsenal. The population consisted of *Dinoderus ocellaris* with a small proportion of *minutus* and *brevis*, each species recurring over the whole period.

Life-cycle: The first generation starting in March is completed in 11 or 12 weeks (pupal stage 4 days). The second generation starting in June is also completed in 11 or 12 weeks with a pupal period of 4 days. The third generation starting at the end of September overwinters as larvae and pupates in March (pupal stage 4 or 5 days), thus taking 22 to 24 weeks from boring in of beetle to emergence of brood. This average rate of development gives 3 generations a year but is varied by the time spent in tunnelling, sexual maturation, pairing, oviposition and incubation; these activities may take 4 to 6 weeks. Under most favourable conditions this period may be reduced to 2 or 3 weeks and sufficient time would than be available for 4 generations in one year at the quickest rate of development.

Emergence-period: The rearing records that have been obtained for *D. ocellaris* and *brevis* for the past twenty years invariably give an annual emergence-graph characterised by three well marked peaks of abundance of emerging beetles, and it is considered that these peaks represent the midpoints of three generations. The peak of maximum abundance of beetles emerging from the overwintered generation falls in the period extending from the middle third of March to the first third of April with the mode in the last third of March; it is separated by an interval of two and two thirds to three and one third months (mode three and one third) from the peak of maximum emergence of beetles of the first generation which falls in the period last third of June to middle third of July (mode last third of June). The peak of maximum emergence of the second generation beetles falls in the period first third of September to last third of October (mode last third of September) and the interval of separation is two and one third to three and two thirds months (mode three months). The interval of separation between the peaks of maximum emergence of the second and third generation beetles, i.e., the duration of the overwintering generation, is thus normally six months. [see fig. 8].

The effect of the moon's phases on the liability of bamboo to attack by borers.

The waning of the moon has been regarded, both in ancient and modern times, and in many lands as the proper season for the felling of timber. During the wane of the moon the sap is believed to flow down leaving the wood dry and more likely to season quickly, whereas the waxing moon is supposed to draw the sap up. On the same principle injurious insects are considered to be more abundant during the waxing and full moon. In India the liability

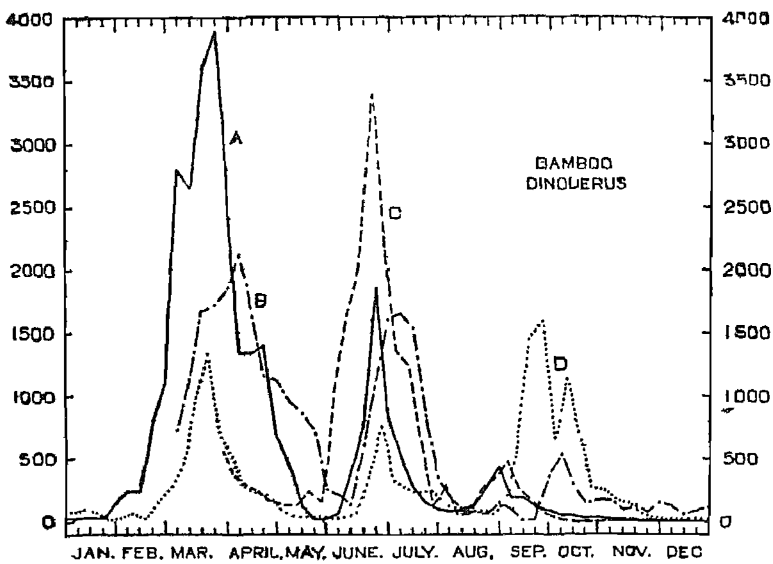


Fig. 8 Emergence-period of *Dinoderus brevis* and *D. ocellaris* breeding in *Dendrocalamus strictus*, showing peaks of three generations. Numbers of beetles emerging at intervals of 7 days. The graphs show four typical cases of emergence periodicity. Graph A is based on material that yielded two-thirds *brevis* and one third *ocellaris* ; Graph B represents an infestation of *ocellaris* and *brevis* with the former slightly in the majority; Graph C is a pure infestation of *brevis*; Graph D yielded about two thirds *brevis* and one third *ocellaris*.

of bamboos to attack by *Dinoderus* is supposed to be highest when the bamboos are cut during the period of moonlit nights and lowest if cut on days with dark nights ; it is explained that the sap is most abundant when the moon is full.

It has been proved experimentally by felling bamboos at fortnightly intervals at the new moon and at the full moon that there is an appreciable fortnightly rhythm in relative moisture-contents of bamboos at any three successive periods (Beeson, 1937). There is a cycle of moisture-percentage increasing from the full moon to the new moon ('rising sap') and decreasing from the new moon to the full moon ('falling sap'); this is the only lunar periodicity known to occur in the metabolism of a growing bamboo. There is no relationship between the moisture-content of a freshly felled bamboo and its subsequent liability to borer-attack. The liability to attack is determined by the quantity of starch and disaccharides present, which varies seasonally not fortnightly. Hence, there is

no advantage in cutting bamboos on dark nights or during the wane of the moon.

Starch-plus-disaccharides content: The starch plus-disaccharides percentage varies from nil to about 20 during the year but also varies from internode to internode. The relationship between starch-content and *Dinoderus* attack in *Dendrocalamus strictus* (at Dehra Dun) is shown in the graphs in fig. 9. It will be seen that the trend of the incidence of borer-damage at over 25 holes (broken line) follows that of the percentage of starch plus-disaccharides (solid line) with appreciable conformity (the chief discrepancy being associated with the unusually high starch-percentage found for the full moon of October and of glucose for the new moon of October). There is an indication that borer damage is on the average high in bamboos felled during the seasons in which the starch-disaccharide-content is on the average high, and when the starch-content is nil there is no borer-attack at all. The subsidiary points ● represent serious attack with a minimum of 500 holes per piece; it is evident that serious attack occurs when the starch-disaccharide-percentage exceeds 5 and in bamboos felled during the period December to April (inclusive).

Best season for felling bamboos.

Stebbing (1914, *tit. cit.* p. 143) summarises the general opinion in the words "the cold weather months are the best ones in which to fell, although felling at this season does not guarantee immunity ......". This dictum had special reference to south India and possibly to localities where *D. minutus* is predominant. Conditions more directly applicable to north-west India (where *D. ocellaris* is predominant) were determined by the Punjab Forest Department in Hoshiarpur division. It was found that the safest time for cutting is firstly May and secondly December; the period from the end of October, throughout November and the beginning of January gave fairly good results; the end of January to the end of April is the worst period. "It, therefore, follows that felling operations should begin towards the end of October at the earliest and cease by the middle of January. The existing practice of carrying out fellings conforms to this conclusion". (1931, *Ind. For.*, LVII, pp. 498–499).

The results of the Dehra Dun experiments based mainly on *D. brevis* [see graph fig. 9] differ slightly in date from those of the Punjab. The liability to attack by borers is least on fellings during the period mid-June to end of July; it is low in the period mid-October to end of December. Fellings done during the first five months of the year are liable to severe damage especially those of March and April. Since contractors do not ordinarily work at the end of the hot weather and early in the monsoon, the immunity obtained by felling in June and July has no practical application.

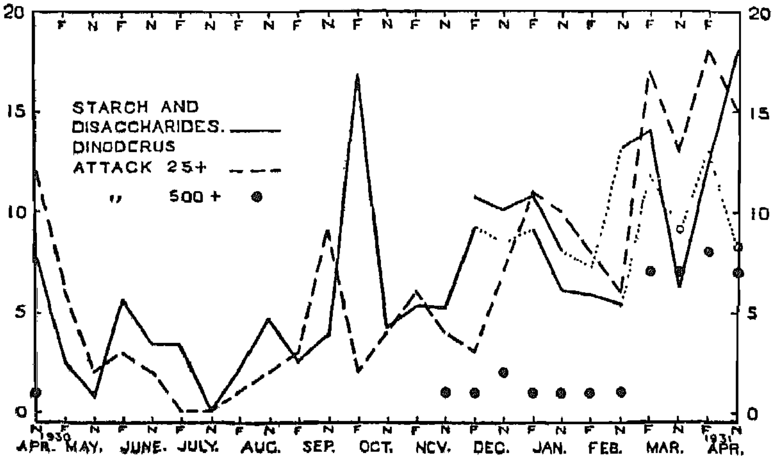


Fig. 9 Starch-and-disaccharides-percentage (solid line) in solid *Dendrocalamus strictus* felled at fortnightly intervals coincident with the new moon and the full moon.

Dinoderus attack in ditto; broken line shows attack of 25 holes and over, solid circles attack of 500 holes and over per 6-foot piece.

The safest period in which to fell (in the Dehra Dun district) is from the end of the monsoon to the end of the December. (1933, *Ind. For.*, pp. 709-712, The liability of solid bamboo lance staves to attack by borers).

It is perhaps not superfluous to point out that the period of attack is not the same as the period of felling. Bamboos felled in the autumn are less liable to be bored in the autumn and winter than from March onwards, because during the cold season the population of *Dinoderus* is less and the beetles are less active. The damage develops from March onwards when the bamboos are concentrated in storage depots often in contact with infested stock held over from the previous year. The normal expectation of loss in ordinary winter fellings is not more than 25 percent owing to variation in the quantity and quality of food-substances in parts of individual culms.

Food value of water-soluble substances in bamboo: It is generally known that bamboos soaked in water for considerable periods are practically immune to attack by *Dinoderus*, and it has been assumed that soaking leaches out certain water-soluble substances, possibly sugars, that are essential for the nutrition of the larva. There is however, no satisfactory experimental proof of either of these beliefs. But it is probable that (*a*) starch is an essential food-substance, (*b*) glucose is not an essential, (*c*) a soluble substance possibly a disaccharide is an essential, and that (*d*) neither of the essentials alone is sufficient.

See also Beeson and Bhatia B.M., 1937, *Ind. For. Rec.*, Ent., II, No. 12, pp. 233-251. On the biology of the Bostrychidae.

Dinoderus bifoveolatus, widely distributed in the tropics and in Burma and south India, is a wood-borer occurring in environments similar to those of *Lyctus*. In south India it attacks planks and shooks of *Bombax malabaricum*, *Kydia calycina* and *Mangifera indica* used for making boxes, and dead saplings of *Artocarpus hirsuta* and *Derris elliptica*. In Africa it bores in canes and palm leaves used for baskets and cases; it also breeds in edible roots and flour, and has been found in flour warehouses in England.

Its emergence-period is extended throughout the year and infested timber may continue to yield beetles for three and a half years. Over 80 percent of the year's population emerges in the seven months August to February with the maximum in January.

Dinoderus brevis, widely distributed in the Oriental Region in *Bambusa arundinacea*, *B. polymorpha*, Cane, *Dendrocalamus strictus* and other bamboos not specifically identified [fig. 4 No.65].

This species primarily breeds in bamboos and the authenticated food plants of the larva are restricted to bamboos and cane. There are several records of boring by the beetle in the wood of dicotyledons which must be regarded as tunnels made for the purpose of feeding or sexual maturation, or shelter during the imaginal stage. Some cases may be due to accidental infestation resulting from contact of timber with larval breeding-material. They are *Albizzia odoratissima*, *Artocarpus hirsuta*, *Balanites roxburghii*, *Bombax malabaricum*, *Butea frondosa*, *Ficus bengalensis*, *Lannea grandis*, *Mangifera indica*, *Pinus khasya* (bark of logs in the Shan States), *Shorea robusta* (wood in the United Provinces), *Sonneratia apetala*, *Sterculia campanulata* (Calcutta), tent-pins of wood (Ordnance stores in the Punjab) and *Tectona grandis* (attracted to newly felled teak in Burma).

For life-history see the foregoing general account of the genus *Dinoderus*. The beetle, natural size 3 mm. is shown in Fig. 4, No. 65.

Dinoderus favosus breeds in *Dipterocarpus pilosus*, *Eugenia jambolana*, and *Shorea robusta*.

Dinoderus gardneri in *Carica papaya*; emergence June-Oct.

Dinoderus mangiferae in *Bridelia stipularis*, *Mangifera indica*, *Murraya koenigii*, small branch wood. The larva is described and figured by Gardner (1933, *Ind. For. Rec.*, p. 8 pl. iii, figs. 28-31 (under the name of *ochraceipennis* Lesne); [see also fig. 11].

Dinoderus minutus

Bambusa, Cane, *Dendrocalamus giganteus*, *D. arundinacea*, *D. hamiltonii*, *D. strictus*, *Oxytenanthera nigrociliata*, *Phyllostachys* sp.

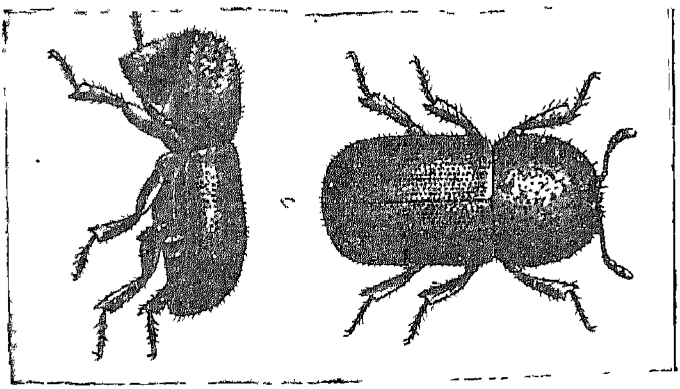


Fig. 10 Beetles of *Dinoderus ocellaris*, Bostrychidae: natural size 3-4 mm.

This species primarily breeds in bamboos and the authenticated food-plants of the larva are restricted to bamboos and cane. There are however numerous records of boring by the beetle in the wood of dicotyledons which must be regarded as tunnels made for the purpose of feeding or sexual maturation or shelter during the imaginal stage, while some cases are undoubtedly due to accidental infestation resulting from contact of timber with larval breeding material. The timbers or plants attacked by the beetle are:—

Albizzia stipulata, *Bombax malabaricum* (stacked planks in plywood and match factories in Assam); *Derris elliptica* (stored roots); *Camellia thea* (stump of tea bush, Ceylon); Madagascar teak (wood in Zanzibar); *Erythrina indica;* Maize in Mauritius and Java; *Persea gratissima* (bark and pericarp of fruit in Zanzibar); *Melia azedarach; Pinus khasya* (bark of logs in the Shan States); *Poinciana elata* (wood in Madras); *Shorea robusta* (wood in United Provinces); *Smilax borbonica* (dry roots in Reunion Is.); *Spondias mangifera; Tectona grandis* (timber during transit from Burma to England); Tobacco (baled tobacco in Java and Sumatra); *Thespesia populnea* (wood in Bombay); *Vateria indica* (wood of log in Ceylon); *Warmia triquetra* (wood of log in Ceylon).

The reports of damage to converted teak shipped from Burma to Europe a few years ago concerned pieces 7 ft. × 3 in. × 9 in. in which tunnels ½ in. to ¾ in. deep were found on arrival at the British port. The discovery of this form of depreciation caused considerable alarm and prejudice at the time. The tunnels were bored by beetles and larvae derived from infested bamboo dunnage in the ship's hold, and penetrated at right angles to the tangential surface for about half an inch and then in some cases turned to run parallel to the axis of the tree for another half inch or so.

Cosmopolitan in the tropics (approximately between the annual isotherms of 18° or 20° C.: Lesne). The life-history of this species is given in the foregoing general account of the genus *Dinoderus.*

The larva is described by Gardner (1933, *Ind. For. Rec.*, XVIII, ix, p. 8).

Dinoderus ocellaris

Dendrocalamus strictus, *Oxytenanthera nigrociliata* and other bamboos not specifically identified.

The normal breeding-material is bamboo and all authenticated food-plants of the larva are restricted to bamboos. As with the other species of bamboo borers the beetle may occasionally make tunnels in the wood of trees, e.g., *Ficus bengalensis* (Hoshiarpur); *Grewia tiliaefolia* (Bombay); *Pinus khasya* (bark in the Shan States); *Pinus longifolia* (Dehra Dun); *Shorea robusta* (U. P.); *Sterculia urens* (Ganjam); *Tamarix dioica* (Punjab); *Tectona grandis* (timber during transit from Burma to England); *Terminalia tomentosa* (U. P.).

The species was first discovered in a chest of coffee in London. The reports of damage to converted teak and *Dipterocarpus alatus* shipped from Burma to Europe a few years ago arose from the discovery of tunnels ½ in. deep on unloading at the British port. This form of depreciation although uncommon was probably not new but it caused considerable alarm and prejudice that was, however, promptly allayed by the investigations of authorities in England and of the Forest Entomologist in Burma. The latter found that the tunnels in teak planks did not penetrate to a greater depth than half an inch and the majority were within one quarter of an inch of the surface; he explained their occurrence as follows:- "the bamboo dunnage holding a heavy population of the borer has produced a generation of beetles during the voyage, and these, which in nature would flight in search of fresh bamboos in a suitable condition for attack, have in the confinement of a ship's hold merely been able to crawl amongst the cargo. In thus crawling they have penetrated between two pieces of teak or behind the ship's dunnage, or between other cargo and the dunnage, and finding themselves unable to progress further have commenced to bore in. Not finding the substances they require in these strange hosts they have vacated or died" (Atkinson, *Ind. For.*, 1933, pp. 226—232: *Burma Forest Bull.* No. 32, 1936, p. 4).

The life-history of this species is given in the foregoing general account of the genus *Dinoderus*. The larva is described by Gardner (1933, *Ind. For. Rec.* XVIII ix, p. 8). The beetle is figured in fig. 10.

Dinoderus perplexus in *Mallotus philippinensis.*

Enneadesmus forficula in *Acacia modesta.*

Heterarthron batillum in *Vatica lanceaefolia.*

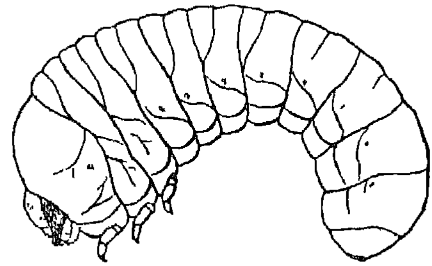


Fig. 11 Larva of *Dinoderus mangiferae*, Bostrychidae natural size 3 mm.

Heterarthron feanus in *Mallotus philippinensis*. Emergence in May. The larva is described by Gardner, 1933, *Ind. For. Rec.*, XVIII, ix, p. 4, figs. 7-12.

Heterobostrychus aequalis.

Adina cordifolia, *Albizzia stipulata*, *Anisoptera glabra*, *Anogeissus acuminata*, Bamboo, *Bambusa arundinacea*, *Bombax anceps*, *Bombax insigne*, *Bombax malabaricum*, *Boswellia serrata*. *Canarium euphyllum*, *Cassia fistula*, *Cedrela toona*, *Dalbergia sissoo*, *Dendrocalamus strictus*, *Dipterocarpus pilosus*, *D. turbinatus*, *Endospermum chinense*, *Garuga pinnata*, *Koompassia malaccensis*, *Kydia calycina*, *Lannea grandis*, *Leucaena glauca*, *Mangifera indica*, *Morus indica*, *Parashorea stellata*, *Parishia insignis*, *Poinciana elata*, *Pterocarpus indicus*, *Quercus* sp., *Shorea leprosula*, *Shorea robusta*, *Sterculia alata*, *Sterculia campanulata*, *Tectona grandis*, *Terminalia belerica*, *Terminalia bialata*, *Terminalia myriocarpa*, *Terminalia tomentosa*. Throughout the Oriental Region to New Guinea.

Alejandro de Mesa (1934, *The Makiling Echo*, XIII, pp. 245-250 and 1935, *tit. cit.* XIV, pp. 93-99) records the food-plants of this species in the Philippines.

H. aequalis is the commonest of the larger bostrychid borers of packing-cases, boxes, plywood chests and panels, sapwood in furniture and fittings of buildings; it is a regular pest in sawmills and in the factories of wood-using industries in India.

L i f e - h i s t o r y: *Heterobostrychus* beetles are black, cylindrical insects with a rough hooded prothorax and usually curved hooks or projections at the hind ends of the elytra; the body-length is 6 to 15 mm. [fig. 4, nos. 60, 61, 62]. The female beetle may lay eggs on the rough surfaces of sawn timber and of logs from which the bark has been removed or may penetrate inside natural crevices and holes, or may bore a short tunnel into the wood for the purpose of feeding and oviposition. Eggs are deposited singly and the larva bores away from the surface a gradually widening tunnel which may reach a length of 15 inches and a diameter of a quarter of an inch. In a crowded infestation a tunnel is generally

much convoluted, changing direction and intersecting the tunnels of other larvae; it is tightly packed with moderately fine wood-dust most of which must have passed through the alimentary canal of the larva. Traces of starch may be present but most of it is digested; in dark coloured woods the dust filling the tunnel is often lighter in colour, which may indicate the removal of more than starch during digestion. The cellular structure is unaltered.

The full grown larva is about 15 mm. long and is described and figured by Gardner (1933, *Ind. For. Rec.*, XVIII, ix, p. 15, pl. IV, figs. 45, 46); [see also text-figure 12].

Pupation takes place in a cell at the end of or in an off-shoot of the tunnel. The immature beetle remains inside the wood for a variable period towards the end of which it is occupied in further boring and feeding among the larval tunnels, finally emerging by an exit-hole on the surface.

Emergence-period: The emergence of beetles takes place during the monsoon season—June to October—reaching its maximum abundance in July, when about 45 percent of the beetle population of the year emerges. In the remaining eight months not more than 7 percent leave the wood [see graph of emergence in fig. 13]. The life-cycle from egg to emerged beetle requires a minimum time of one year, but it is usual for a large fraction of the larval brood resulting from eggs laid at one season to take two or three years to complete development. The longest period recorded for the life-cycle is five years (in plywood) and six years (in opium chests of semul).

Nature and extent of damage.

Starch: The extent of the damage done by the borings of *H. aequalis* is determined by the nature and dimensions of the wood infested by the borer and is confined to wood that contains starch. That starch is an essential constituent of the food of the *Heterobostrychus* larva has been experimentally determined in *Bombax malabaricum*. If a tree is felled and the bole is not cross-cut into logs and the crown branches are not severed, the bark remains green for several months (and often produces epicormics); during this period the starch in the outer zones of the wood is depleted and the wood is rendered unsuitable as food for *Heterobostrychus*. Similar conditions are produced if logs are stored in water. If a newly felled tree is straightway converted and the planks, etc., are quickly dried out they contain fixed starch and are liable to attack; if the planks are stored in excessively humid atmosphere fermentation and fungus-attack sets in and starch disappears before *H. aequalis* larvae can complete the early instars.

Logs, planks and plywood: When barked logs are heavily attacked the wood is reduced to powder to a depth of two or three inches except for a residual skeleton or network. In soft-

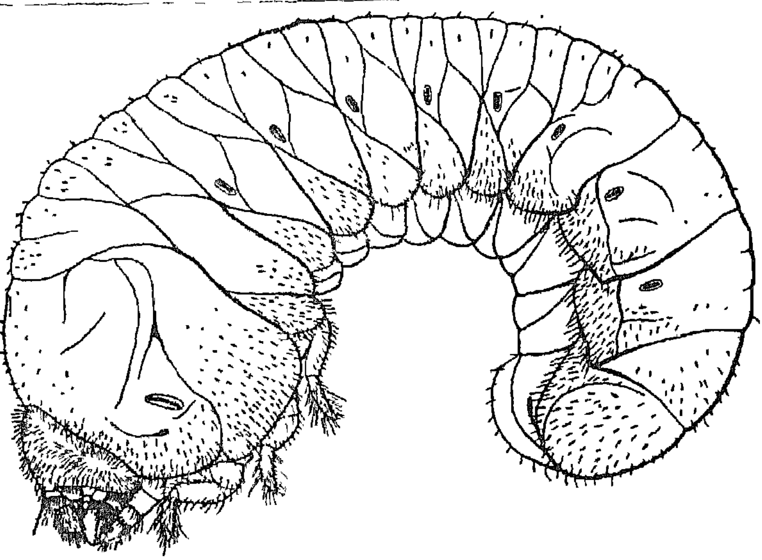


Fig. 12 Mature larva of *Heterobostrychus aequalis*, Bostrychidae : natural size 11 mm.

woods the damage may extend deeper; in hardwoods with well marked heartwood the penetration is confined to the sapwood. Fig. 14 No. 1 shows a log of *Garuga pinnata* with larval tunnels (upper half) and emergence holes (lower half). In planks, etc., attacked after conversion the larvae are forced to extend their tunnels in the plane of the plank. Fig. 14 No. 2 shows larval work in a plank of *Terminalia bialata*; in the upper half the planed and varnished surface remains as a thin paper-like sheet over a solid mass of dust. In plywood the larval tunnel usually starts from the edge of a panel where the egg has been deposited in a cross cut vessel and runs thereafter with the grain keeping to one sheet of veneer until the diameter of the body of the larva exceeds the thickness of the veneer. When two panels are in contact as in a stack or bundle the tunnel of the mature larva may run in both of the outer veneers in contact; when the tunnel starts in a middle veneer it may pass into one of the outer veneers in its later stages. The beetle before it leaves the panel of plywood bores irregular tunnels that affect two or more veneers and may pass into adjacent panels.

Fig. 16 shows the course of tunnels of *H. aequalis* in three plywood starting from eggs laid at the edge of middle or outer veneers. The tunnels in the right hand strip show change of direction at right angles on passing from one veneer to the next. The tunnel in the central strip is confined to one veneer and keeps to the direction of its grain. The tunnels in the left hand strip are common

to the outer faces of two adjacent panels and are the work of emerging beetles. Fig. 14 No. 3 shows tunnels in an outer veneer, which are beetle work (right and central) and larval work (left). Emerging beetles will bore through a thickness of one or two inches and will also make holes through the lead foil lining of tea boxes.

For control see Part Two, Bostrychidae, Heterobostrychus; also Garthwaite P.F., 1940, *A guide to the borers of commercial timber in Burma.*

Heterobostrychus hamatipennis in *Acacia catechu*, *Anogeissus latifolia*, bamboos, *Bombax malabaricum*, *Boswellia serrata*, *Canarium strictum*, *Dalbergia sissoo*, *Dendrocalamus strictus*, *Eugenia jambolana*, *Garuga pinnata*, *Machilus* sp., *Mallotus philippinensis*, *Mangifera indica*, *Quercus* sp. *Shorea robusta*, *Terminalia belerica*, *Vatica lanceaefolia*. Occurs throughout the Oriental Region.

H. hamatipennis breeds in logs and branchwood; it has not been found in converted timber in factories. The life-cycle is annual with emergence in June-July (about 70 percent in June). The larva, 17 mm., is described by Gardner, 1933, *tit. cit.*, XVIII, ix, pp. 14. 15, figs. 47-49.

Heterobostrychus pileatus, in *Acacia pennata*, *Cassia fistula*, *Garuga pinnata*, *Lannea grandis*, *Mallotus philippinensis*, *Mangifera indica*, *Mangifera* sp., *Pavetta indica*, *Santalum album*, *Shorea robusta*, *Sindora siamensis*, *Zizyphus* sp.

This is a forest-inhabiting species rather than a depot and factory pest, but it has been intercepted in Queensland in the wood of tea-chests imported from India. The life-cycle is annual with emergence in April to June, over 70 percent emerging in April. No case of emergence delayed to the second year has been observed. The larva, 12 mm., is described 1933, *tit. cit.*, XVIII, ix, p. 15, fig. 52.

Heterobostrychus unicornis in *Butea frondosa*, and *Shorea robusta*.

Lyctoderma ambiguum in *Acacia catechu* and *Dalbergia sissoo*, emergence throughout the year but mainly in October.

Lyctoxylon beesonianum in *Shorea robusta* in the United Provinces.

Reared from branchwood caged in April and yielding beetles in November to March and again the following year in March, April. It occurred in association with *Sinoxylon pygmaeum* and *Xylodectes ornatus* (Bostrychidae).

Lyctoxylon convictor in *Acacia gageana*, *Mangifera indica* and bamboo.

Collected in a dead stem of mango in April in association with *Sinoxylon atratum kohlarianum*, one *Lyctoxylon* and one *Sinoxylon* in each tunnel. M. Lesne regards this association as an example of commensalism similar to those observed by him for

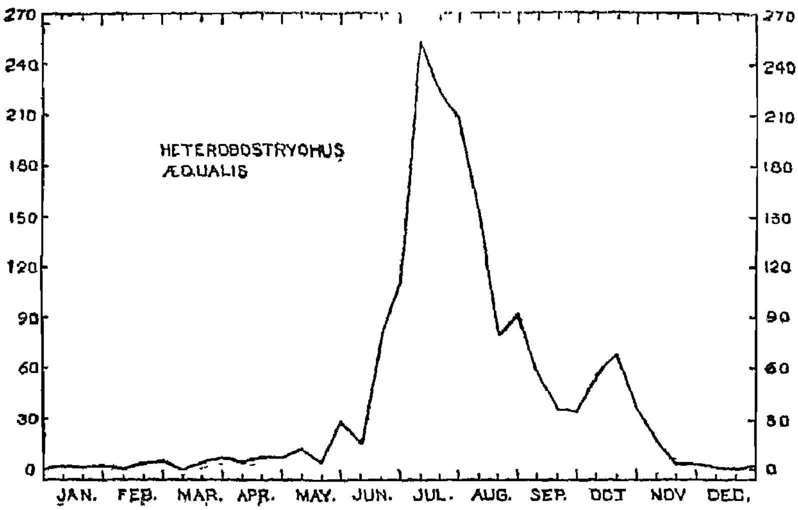


Fig 13. Emergence-period of *Heterobostrychus aequalis.* Numbers of beetles emerging at intervals of one third of a month.

African bostrychids (1932, *Soc. Ent. France*, *Livre Centenaire*, pp. 620-627). Bred from *Acacia gageana* in May in association with *Sinoxylon atratum kohlarianum*, *S. capillatum*, *S. crassum*, *S. oleare* and *Xylodectes ornatus* (Bostrychidae).

Lyctoxylon japonum in *Acacia gageana*, *Ailanthus malabarica*, *Albizzia procera*, Bamboo, *Bauhinia vahlii*, *Bombax malabaricum*, Cane, *Castanopsis argyrophylla*, *Cinnamomum inunctum*, *Dalbergia latifolia*, *Dendrocalamus strictus*, *Lannea*

Fig. 14 Damage to wood by Bostrychidae.

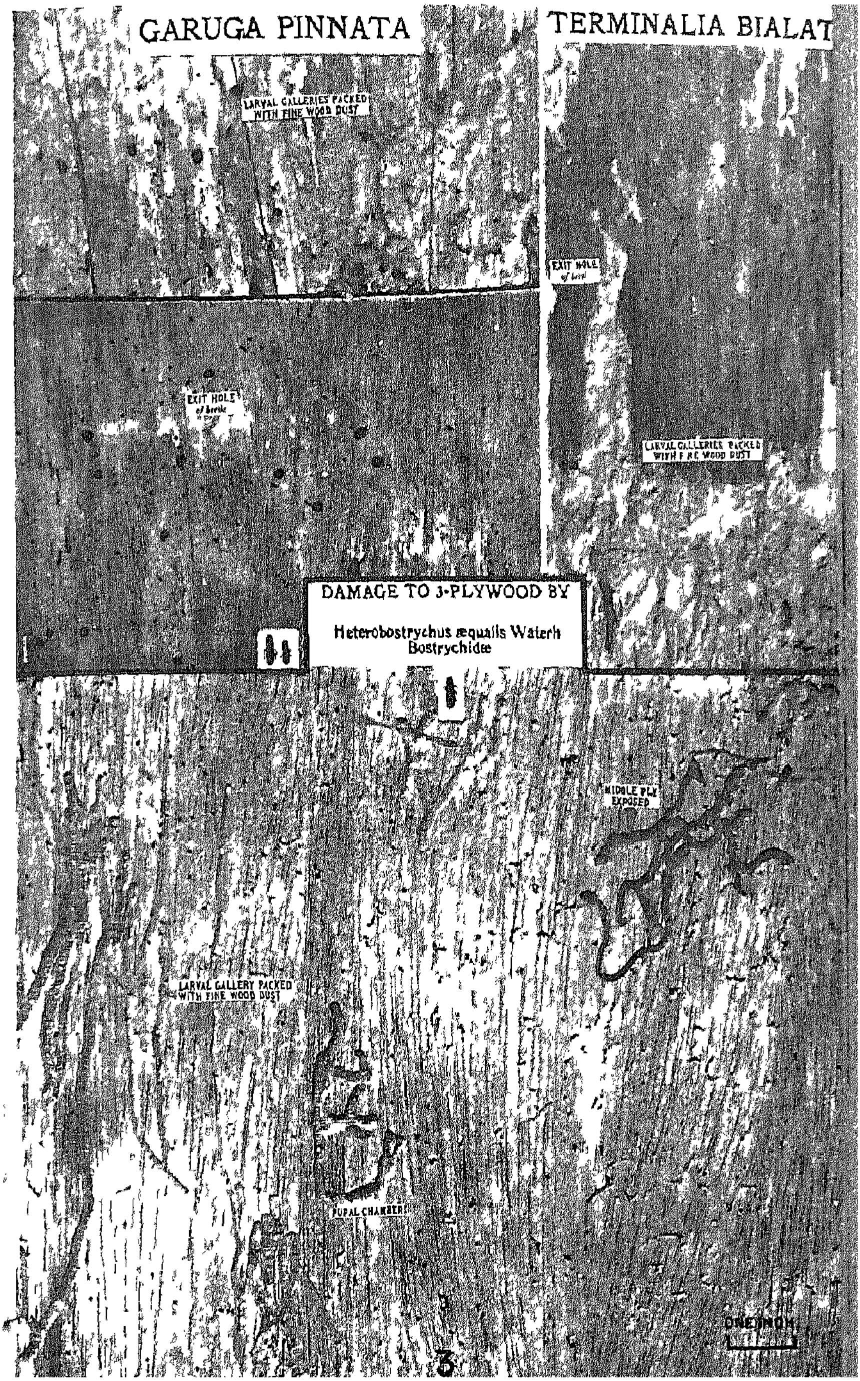
No. 1. *Garuga pinnata* log attacked by *Heterobostrychus aequalis.* Lower portion shows circular emergence-holes of beetles on the surface of sapwood; upper portion with outer layer of sapwood removed showing larval galleries packed with fine wood-dust.

No. 2. *Terminalia bialata* plank, planed and varnished, attacked by *Heterobostrychus aequalis.* Upper part shows thin paper-like sheet over mass of larval galleries packed with fine dust.

No. 3. 3 plywood panel attacked by *Heterobstrychus aequalis.* Beetle work in outer veneer (right and central), and larval work (left).

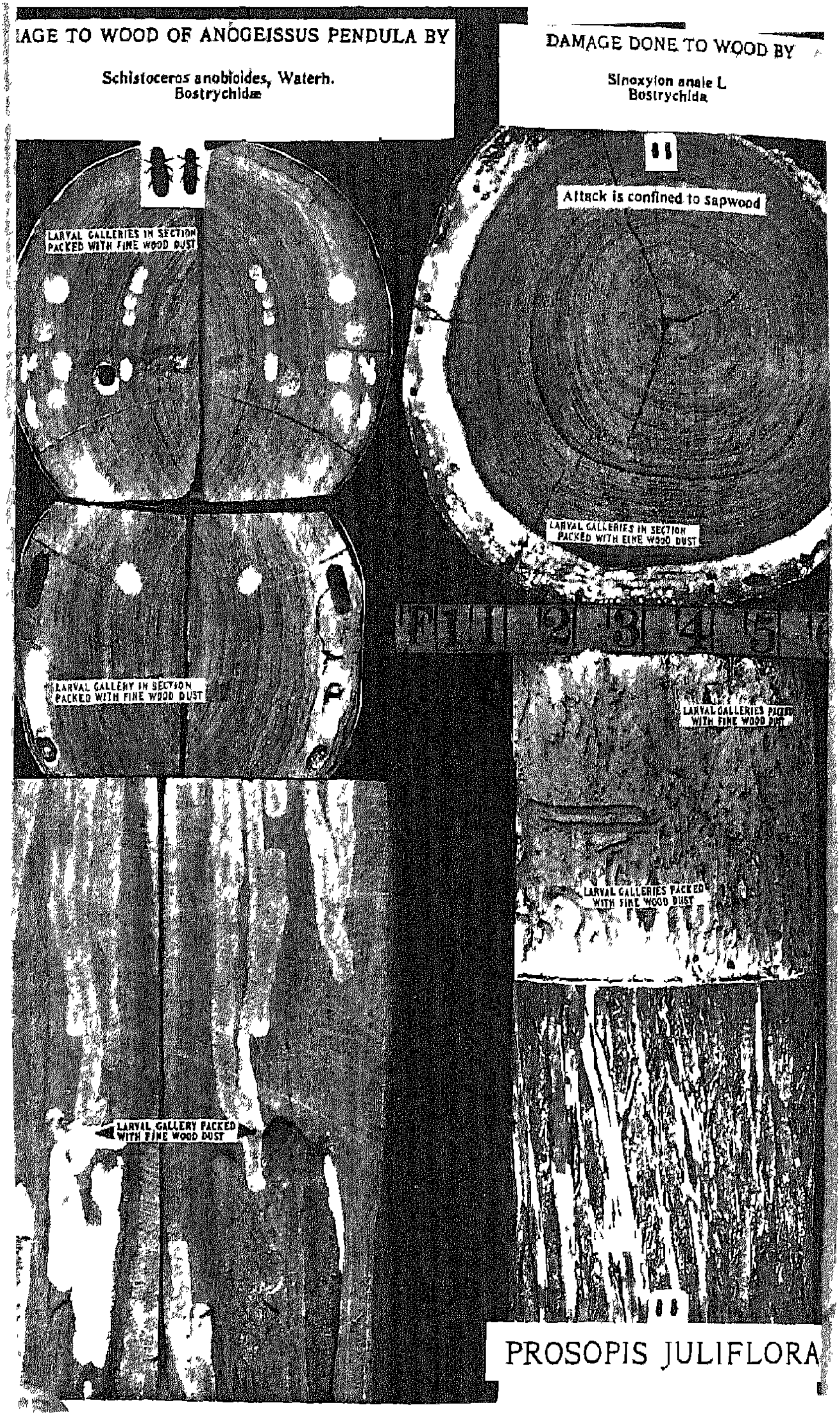
The small holes and galleries are the work of *Lyctus africanus.*

All specimens on the same scale indicated by the one inch line in the bottom righthand corner.



DAMAGE TO 3-PLYWOOD BY

Heterobostrychus æqualis Waterh
Bostrychidæ



IAGE TO WOOD OF ANOGEISSUS PENDULA BY
Schistoceros anobioides, Waterh.
Bostrychidæ
LARVAL GALLERIES IN SECTION PACKED WITH FINE WOOD DUST
LARVAL GALLERY IN SECTION PACKED WITH FINE WOOD DUST
LARVAL GALLERY PACKED WITH FINE WOOD DUST
DAMAGE DONE TO WOOD BY
Sinoxylon anale L
Bostrychidæ
Attack is confined to sapwood
LARVAL GALLERIES IN SECTION PACKED WITH FINE WOOD DUST
LARVAL GALLERIES PACKED WITH FINE WOOD DUST
LARVAL GALLERIES PACKED WITH FINE WOOD DUST
PROSOPIS JULIFLORA

grandis, *Litsaea sebifera*, *Michelia* sp., *Prosopis spicigera*, *Sterculia campanulata*, *Terminalia belerica*, *Terminalia myriocarpa*, *Thespesia populnea*.

A cosmopolitan species but probably confined to the wetter regions of India. It was reported as infesting the cane used for strengthening bales of yarn in Madras, in company with *Dinoderus brevis* and *D. minutus*; the beetles emerging from the cane bored into the yarn causing considerable damage to it. It attacks tea-chests in Ceylon but is apparently not as common as *Lyctus brunneus* in factories. It has been found in ships' dunnage in Rangoon dockyard. The remaining records are from small wood, fuel and bamboo. It has been introduced into the United States in commercial articles made of bamboo from Japan and China. In Japan the usual host is *Arundinaria simoni*.

The larva, 3 mm., is described by Gardner, 1933, *Ind. For. Rec.*, XVIII, ix, p. 11, pl. 11, figs. 13, 14. [See also text-figure 18].

The emergence-period is unusual as it is concentrated in the colder season. Over 83 percent of the annual population emerges in September to February inclusive with 20 percent in December; in the hot and dry weather emergence is at its lowest (in the case of material caged at Dehra Dun). The normal life-cycle is probably annual. The longest period of infestation is over three years.

The Lyctinae or Lyctus Beetles.

The group Lyctinae or "Lyctus Beetles" comprises several species of the genera *Lyctoderma*, *Lyctoxylon*, *Lyctus*, *Minthea* and *Trogoxylon* of comparable habits but of variable economic importance. The species of *Lyctus* and *Minthea*, generally known as "Powder-post Beetles" from the manner in which the larvae reduce attacked wood to a fine flour-like powder, are of considerable economic importance as pests of sawmills and wood-using factories and of furniture and wooden fittings in buildings. Extensive research on the biology of species of *Lyctus* has been done by several investigators in the United States, England and

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Fig. 15. Damage to wood by Bostrychidae.

No. 1. Right side—*Prosopis juliflora* attacked by *Sinoxylon anale*. Above, cross-section showing larval tunnels packed with dust or empty, confined to sapwood. Below, lower portion showing holes of beetles in bark; upper portion showing larval tunnels packed with wood-dust, mostly running vertically, and two beetle tunnels running horizontally.

No. 2. Left side—*Anogeissus pendula* attacked by *Schistoceros anobioides*. Above, cross-section showing larval tunnels packed with dust or empty, penetrating to middle of log. Below, longitudinal section showing larval tunnels running vertically and into centre of log.

All material to the same scale indicated by inches on tape.

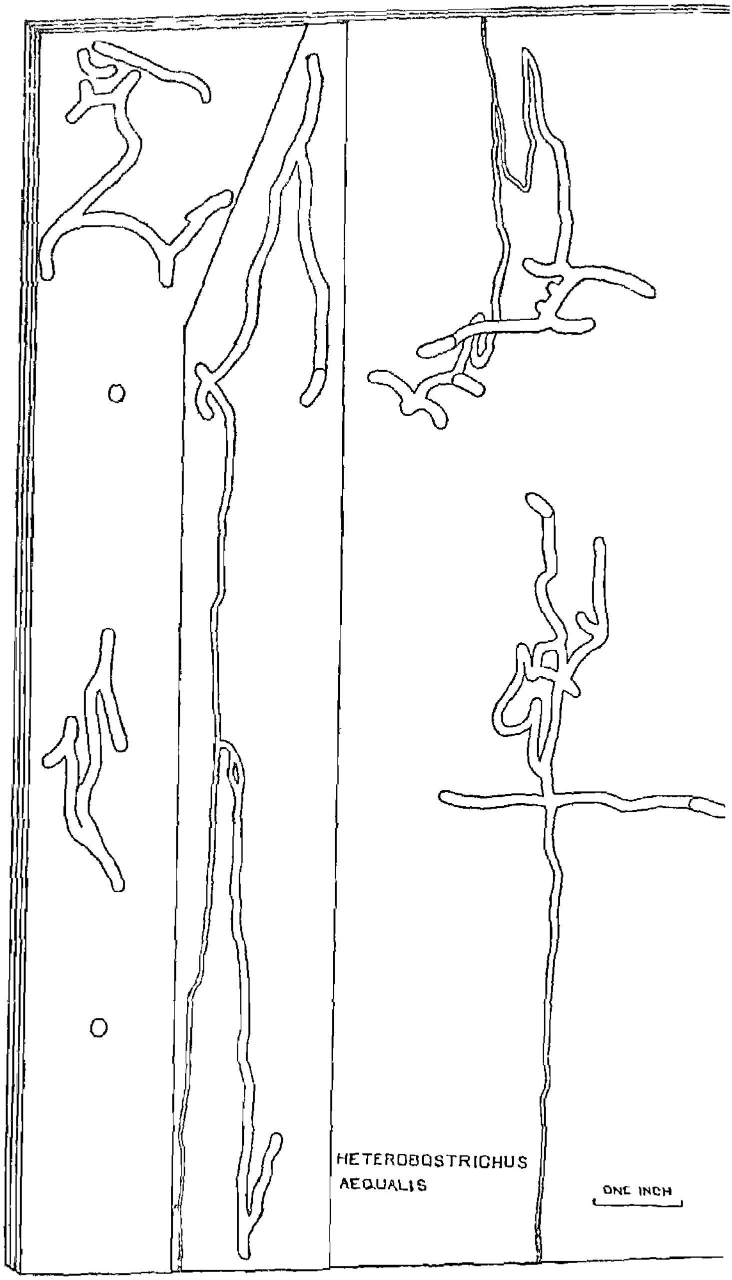


Fig 16 3 plywood panel showing work of *Heterobostrychu aequalis*, larval and beetle tunnels in different veneers Fo explanation see text, page 66

Australia. (Altson, Campbell, Cann, Cummins, Fisher, Kojima, Parkin, Snyder, Wilson and others). The following general account summarises the observations of these workers in so far as they are applicable to Indian species and Indian conditions.

The adult Lyctus beetles are 2 to 7 mm. (about one-sixth of an inch) long, flattened, light brown to almost black, some species with white scales. [See figs. 20*a*, *b*.] The egg is a slender cylinder 800 to 1,000 microns long, six to eight times as long as wide, rounded at one end, and produced in a thin strand or filament at the other end. The larva has evident three-segmented legs and the body form shown in fig. 18; the full grown length may be a quarter of an inch. The larvae of *Lyctus africanus, L. brunneus, Lyctoxylon japonum, Minthea rugicollis* and *Trogoxylon auriculatum* are described by Gardner (1933, *Ind. For. Rec.*, XVIII, part ix, Immature stages of Indian Bostrychidae).

Life-history.

Lyctus beetles may live several (8–9) weeks but the length of life is reduced and activity is greater at temperatures above 20° C. During daylight they usually conceal themselves in cracks or holes in wood but become active at dusk and readily take flight; they are attracted to light. They feed on the surface of wood by gnawing torn fibres. Pairing may take place shortly after emergence and be repeated throughout life.

Oviposition: Eggs are inserted in the open pores or vessels exposed on transverse or longitudinal surfaces of sawn wood. More than one egg may be deposited within the same vessel, the deepest being as much 7 mm. from the aperture. Normally they are never deposited in cracks or on planed or polished surfaces. The diameter of the vessels in which oviposition occurs may be greater than the normal diameter of the egg or slightly less; in the latter case the vessel diameter must be great enough to allow the introduction of the ovipositor. The egg is considerably elongated in its passage down the ovipositor and as it issues from the aperture of the ovipositor it expands in diameter and decreases in length to regain its normal dimensions. If the vessel in which the egg is laid is smaller than the normal diameter of the egg this expansion is not possible and an abnormally elongate egg results. The susceptibility of timbers to Lyctus attack is thus governed primarily by the relationship between pore-diameter and ovipositor-diameter.

The diameter of the ovipositors of Indian species of *Lyctus* lies between 50 and 90 microns. It is theoretically *possible* for any timber containing pores large enough for the introduction of the ovipositor to be attacked, i.e., any timber having some vessels with a minimum average diameter of about 60 microns. But timbers which are regularly susceptible to Lyctus damage are those having an abundance of pores of much greater diameter.

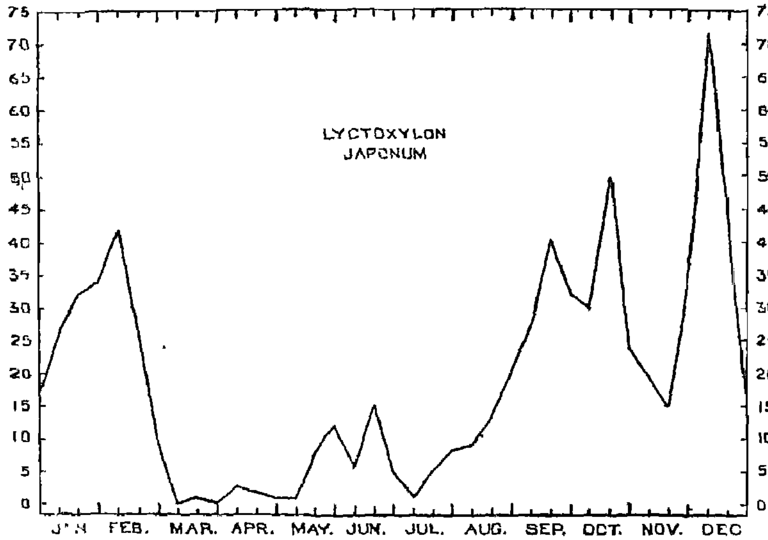


Fig. 17. Emergence-period of *Lyctoxylon japonum.* Numbers of beetles emerging at intervals of one-third of a month.

The limiting minimum diameter is probably between 90 and 130 microns. Very small pored woods and coniferous woods are not subject to Lyctus attack. Chowdhury (1933, *Ind. For.* 59, pp. 164-170, The liability of some Indian timbers to Lyctus attack) gives the measurements of the pore-diameters of about 50 species of timbers subject to damage by *Lyctus africanus.* Ring-porous and diffuse-porous woods are most susceptible. A second essential is the existence of starch in the wood (see below). The number of eggs that may be laid by one female is about 30-50.

Larval tunnels: As soon as the embryo in the mature egg is fully developed it feeds on the residual yolk mass whilst still enclosed in the chorion. Hatching takes place in one to two weeks and the young larva tunnels usually along the vessel, i.e., with the grain. In large pored wood it often follows the course of one vessel for several centimetres before its tunnel expands into adjacent vessels; in small pored wood the initial tunnel is often at an angle to the site of the egg. The wood-tissue eaten by the larva is reduced to a very fine powder (passing through a 120 mesh screen) and is packed closely in the tunnel behind it. This fine flour-like frass, which is a conspicuous sign of Lyctus damage, has given the name "Powder-post Beetles" to these borers. In its later stages the larval tunnel takes an irregular course often recrossing its earlier track or intersecting the tunnels of other larvae. Tunnels approach the surface of infested wood but do not penetrate it, leaving a thin unbroken skin.

Food of larva: Starch in the cell-contents forms the chief source of food of Lyctus larvae; the substance of the cell-wall is not utilised as food. The intestine contains digestive enzymes which are able to hydrolyse soluble starch and several disaccharides and a polysaccharide which does not ordinarily leach out of air dry wood with water. The larva is unable to digest cellulose and hemicellulose; the relative proportions of cellulose, pentosans and lignin in sapwood are not changed during the passage of the wood-particles through the intestine of the insect. The floury frass or faecal matter of the larva is almost entirely devoid of starch. Wood-boring insects that derive their nutriment from included carbohydrates must ingest relatively large quantities of wood in order to extract sufficient digestible substance for their growth. A Lyctus larva may be compared to an earthworm in this respect. Hence the amount of frass produced as excrement by a Lyctus larva during its life time is very many times its own bulk. A brood of larvae may reduce infested wood completely to powder except for a thin skin which is left intact on the surface until the adult beetle cuts its way out.

The presence of starch in sapwood is essential for infestation by Lyctus to occur and although starch is not its sole food the greater the starch-content the greater the possible extent of damage. Below a minimum concentration of starch no attack occurs. In addition to starch a water-soluble substance is necessary for the normal growth of the larva. Female beetles are able to detect the suitability of timber for oviposition, in relation to its food-value for larvae.

Moisture is necessary for the normal development of the larva. It will thrive in wood with a moisture-content between 50 and 10 percent, the higher moisture-content being the more favourable. Wood with less than 10 percent moisture is not attacked.

Pupation: When full grown the larva tunnels towards the surface of the wood and prepares an oval chamber for pupation. The pupal period is about one month.

Emergence: The newly formed beetle cuts its way out by a more or less circular hole, 1 to 1·5 mm. (1/32nd to 1/16th of an inch) in diameter. The circumference of the exit-hole is not clear-cut and regular as in that of a pinhole borer. A small pile of dust is pushed out of the hole by the emerging beetle. Dust also escapes from these holes and from large pores as a result of the tunnelling of larvae of later broods. Beetles will bore through varnish, paint, glue, lead foil, etc., or hard heartwood in order to escape.

Life-cycle: The normal development cycle is on an annual basis in north India, i.e., a batch of eggs laid in one year is capable of producing beetles in the corresponding season of the following year. But under favourable conditions a portion of the

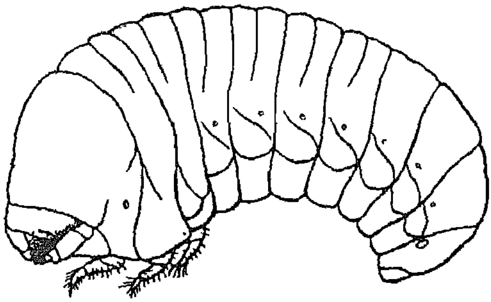


Fig. 18. Larva of *Lyctoxylon japonum*, natural size 3 mm. Note size of last abdominal spiracle.

brood develops at a quicker rate which may allow a succession of two or three generations in a year. If development is delayed owing to deficiency of food-substances or to seasonal decrease in the moisture-content of the wood the life-cycle may extend for several years (up to eight). The emergence-period of a generation is ill defined and extends over several months but in some species it is more restricted and definitely seasonal (see life-cycles of species).

Lyctus africanus.

Acacia arabica, *Acacia gageana*, *Acacia modesta*, *Albizzia lebbek*, *Albizzia procera*, *Albizzia stipulata*, *Alnus nepalensis*, *Alstonia scholaris*, *Artocarpus hirsuta*, Bamboo, *Bambusa arundinacea*, *Bauhinia vahlii*, *Bauhinia variegata*, *Bombax malabaricum*, *Boswellia serrata*, *Buchanania latifolia*, *Butea frondosa*, *Canarium euphyllum*, Cane, *Cassia fistula*, *Cedrela toona*, *Cinnamomum inunctum*, *Clerodendron infortunatum*, *Cynometra polyandra*, *Dalbergia latifolia*, *Dalbergia paniculata*, *Dalbergia sissoo*, *Dendrocalamus strictus*, *Derris elliptica*, *Dipterocarpus turbinatus*, *Embelia robusta*, *Erythrina suberosa*, *Euphorbia* sp., *Ficus glomerata*, *Ficus hispida*, *Ficus infectoria*, *Ficus palmata*, *Ficus religiosa*, *Ficus rumphii*, *Garuga pinnata*, *Gmelina arborea*, *Grevillea robusta*, *Grewia tiliaefolia*, *Grewia vestita*, *Holigarna arnottiana*, *Kydia calycina*, *Lagerstroemia lanceolata*, *Lagerstroemia parviflora*, *Lannea grandis*, *Macaranga roxburghii*, *Mallotus philippinensis*, *Mangifera indica*, *Melanorrhoea usitata*, *Millettia auriculata*, *Nyctanthes arbor-tristis*, *Parashorea stellata*, *Phyllanthus emblica*, Pith, *Pithecolobium dulce*, *Pongamia glabra*, *Populus euphratica*, *Prosopis juliflora*, *Prosopis spicigera*, *Pterocarpus marsupium*, *Pterospermum acerifolium*, *Quercus semecarpifolia*, *Quercus* sp., Red pine, *Sarcocephalus cordata*, *Shorea robusta*, *Soymida febrifuga*, *Spondias mangifera*, *Sterculia alata*, *Sterculia campanulata*, *Sterculia urens*, *Swietenia mahagoni*, *Tectona grandis*, *Termi-*

nalia arjuna, *Terminalia belerica*, *Terminalia bialata*, *Terminalia myriocarpa*, *Terminalia tomentosa*, *Thespesia populnea*, *Vateria indica*, *Vatica lanceaefolia*, *Wendlandia exserta*, *Wrightia tinctoria*, and unidentified woods.

Lyctus africanus attacks logs, branchwood and stumps of felled trees in the forest and practically every kind of manufactured wooden article that contains sapwood, e.g., packing cases, shooks, planks, boards, battens, wooden framework and fittings in buildings, furniture, tool handles, plywood, single veneers and also large woody seeds and roots, bamboos and canes. An example of the damage done by this species to 3-plywood is given in Fig. 14, No. 3. It can complete its life-cycle in material as thin as a sheet of veneer and an infestation is not checked by surface-treatments with preservatives containing oils or water-soluble poisons. It has been reared in roots of *Derris robusta*, a fish poison. The beetle lives for several days in an atmosphere strongly charged with the vapour of paradichlorobenzene.

It is the commonest species of Lyctus beetle in north India under "natural" conditions and is widely distributed by trade throughout India in infested packing cases, furniture and wooden articles generally. The original boundaries of its natural habitat are no longer discernable but it is probable that it is not indigenous in the moist tropical and subtropical regions. Except in artificial environments such as factories, mills, ordnance store depots, large buildings, etc., it is replaced in these regions by *Lyctus brunneus* and *Minthea rugicollis*; and there are some timber mills (e.g., in the Andamans and northeast Assam) where it has not been discovered and is apparently not yet introduced.

The beetle of *L. africanus*, 2–4·5 mm., does not display the wide range in size characteristic of *L. brunneus*, 2·2–7 mm., and is on the average a much smaller insect. See figure 20*a*, page 79 and fig. 4, No. 64 for an outline enlarged and a natural size illustration of the beetle. The larva is described and figured by Gardner (1933, *Ind. For. Rec.*, XVIII, ix, p. 12, pl. ii, figs. 15-19). Measurements of the egg are given by Chowdhury (1933, *Ind. For.*, 59, p. 165) who found the maximum diameter to be 130 microns and the width at the narrowest part 108 microns.

Life-history

Emergence-period: Ordinarily there is very little emergence during the first three months of the year—at the most irregular series of individuals amounting to a small percentage of the annual total. At the beginning of the warm weather there is a fairly sudden increase in the number of emerging beetles which rapidly rises to a high peak. This phase of abundant emergence usually commences in the first half of May (but may be as early as the middle of April, or as late as the end of May), and lasts for three or four weeks and then falls to relatively low figures.

[*Contd. on page 77*]

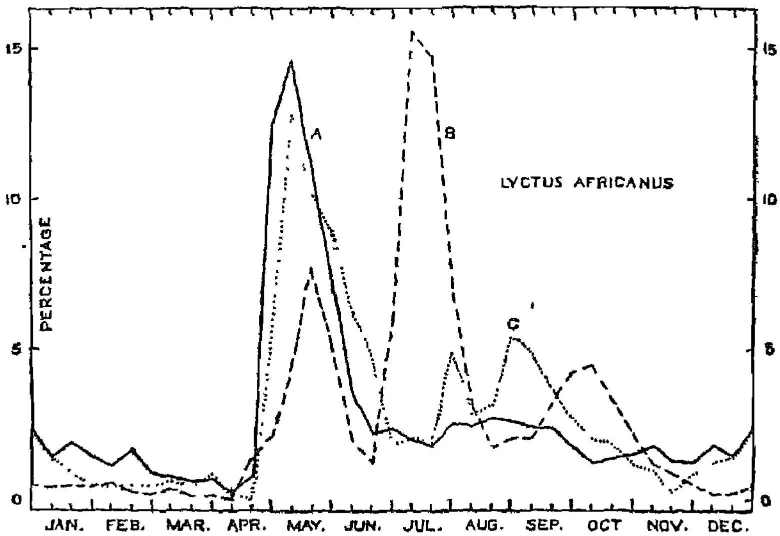


Fig. 19. Emergence-period of *Lyctus africanus*. Numbers of beetles emerging at intervals of 1/3rd of a month.

For comparison, the data for the ten-day periods have been reduced to percentages of the total annual population.

(*a*) Graph A (solid line) represents the emergence from bamboos, *Dendrocalamus strictus*, from sale depots and tent-poles from military arsenals ; the numbers of beetles reared was 16,635. Note that there is one outstanding peak of high abundance culminating at the beginning of May with 14·66 percent emerging in ten days, while for the rest of the year the periodic abundance does not rise above 2·68 percent (mid-August). This form of emergence-graph appears to be characteristic of bamboo and is not the result of seasonal weather conditions or the period and intensity of the original infestation. It is repeated year after year in the same piece of infested bamboo.

(*b*) Graph B (broken line) represents the emergence from wooden tent-pins of several species of wood (mainly sapwood) from military arsenals : the number of beetles reared was 15,902. Note that there are three well marked peaks of high abundance culminating in mid-May (7·7 percent), first third of August (15·53 percent) and last third of September (4·24 percent), and that the first peak of the year is not the highest. The well-marked peak during the monsoon (usually August) is characteristic of emergence from timber in the log or branch.

(*c*) Graph C (dotted line) represents the emergence from panels of three-plywood—the most artificial of the environments of *L. africanus ;* the number of beetles represented is 11,625. Note that there is a combination of a dominant peak in the first third of May (12·71 percent) with subsidiary peaks at the end of July (4·92 percent) and the end of August (5.45 percent).

Beetles continue to emerge for the rest of the year in varying abundance which may increase at one or two periods to numerically high peaks, that are not usually so high as the first peak of the year but may, under certain conditions, surpass it. When there are two periods of high abundance the second usually commences in July and extends into August and September, with the peak about the end of August. When there are three periods of high abundance in the annual emergence the second falls in the interval between the beginning and the end of the rainy season; and is followed by a third emergence peak at any time in the cold season between the middle of November and early January. In exceptional conditions this activity may be prolonged but at a very low level well into March.

The emergence-period of *Lyctus africanus*, after the first swarms in May, is so variable that it is difficult to say what is the normal behaviour of the species. The nature of the food-supply and its physical condition are certainly factors of primary importance in determining the developmental rhythm. The three emergence-graphs contrasted in fig. 19 illustrate the effect of the food-supply.

Number of generations: *L. africanus* may complete three generations a year (in north India), the commencement of each corresponding with one of the three dominant peaks in the emergence-graphs. As with other Lyctus beetles and bostrychids in general a portion of the population developing from one brood of eggs matures at the rate necessary to produce three generations a year and the remainder matures at slower rates equivalent to two or three or more short life-cycles. Larval development may be prolonged for several years, at least seven years, and probably more.

From the economic point of view there are two aspects of the life-cycle to consider, i.e., the shortest cycle and the longest period of infestation of one and the same piece of wood; in other words, how soon a piece of infested wood will yield beetles capable of attacking other stock and how long the danger will continue.

Minimum life-cycle; The rate of development from May to September gives a minimum life-cycle of four months; the rate of development from a November or December oviposition gives a minimum life-cycle of six months. Hence, attacked wood showing holes made by emerging beetles in the autumn was attacked not less than four months previously; wood showing the first holes early in the year was attacked not less than six months previously.

Maximum period of infestation: The longest period over which emergence has extended is seven years and ten months. Sixty-six months has been recorded in the case of mango planking used for making opium chests- Periods of up to fifty-two months have been recorded for wooden tent-pins obtained from military

arsenals in India. Three or four years is quite usual for plywood, furniture, and woodwork in buildings.

Liability of seasoned and unseasoned wood to attack.

The frass of *Lyctus africanus* is almost entirely depleted of starch and it is presumed that starch and its associated disaccharides form an essential part of the food-supply. The borer will attack unseasoned wood a short time after the tree has been felled. By felling a series of trees of *Shorea robusta* monthly throughout the year and leaving logs in the forest for various periods it was observed that newly felled timber is not attacked during the first month but begins to be suitable for oviposition during the second and subsequent months. A heavier attack occurred on logs stored in the sun than on logs stored in the shade indicating that a certain amount of drying out is essential.

Bamboo *(Dendrocalamus strictus)* is suitable for attack within five weeks of felling and larvae develop successfully to beetles in three or four months.

Bombax malabricum, converted into planks within a few days of felling, is suitable for infestation if air-seasoned, but if the planks are confined in a humid atmosphere and prevented from drying out the consequent fermentation and growth of fungi kills off any *L. africanus* larvae that may hatch out.

It has not been ascertained experimentally if eggs laid on old seasoned wood can give a successful infestation, but it may be presumed that the presence or absence of starch is the decisive factor.

For control measures see Part Two, Bostrychidae, Powder-post Beetles.

LITERATURE :
Beeson and Bhatia B.M., 1937, *Ind. For. Rec.*, Ent., II, 12, pp. 269-276.
Garthwaite P.F., 1940, A guide to the borers of commercial timber in Burma, pl. VI, figs. 2, 3.

Lyctus brunneus.

Albizzia odoratissima, *Artocarpus integrifolia*, *Bombax malabaricum*, *Canarium euphyllum*, *Dipterocarpus pilosus*, *Erythrina indica*, *Grevillea robusta*, *Kydia calycina*, *Mangifera indica*, *Michelia champaca*, *Michelia oblonga*, *Quercus* sp., Red pine, *Terminalia belerica*, *Terminalia bialata*, *Terminalia myriocarpa*, *Terminalia tomentosa*, and unidentified woods.

Roughly and Welch (1923, *Tech. Mus. Sydney*, *Bull.* No. 8, p. 25, 26) list species of Australian timbers the sapwood of which is attacked by *L. brunneus*. Cummins and Wilson (1934, *J.Counc. Sci. Ind. Res.*, 7, p. 230) give a similar list of Australian timbers. Lesne (1924, *Bostrych. Afr. Tropicale*, p. 84) gives a list of timbers attacked by this species in tropical Africa, north Africa and Indo-China. Muriemoto Yano (1933, *Bull. Imp. For. Expt. Sta.*

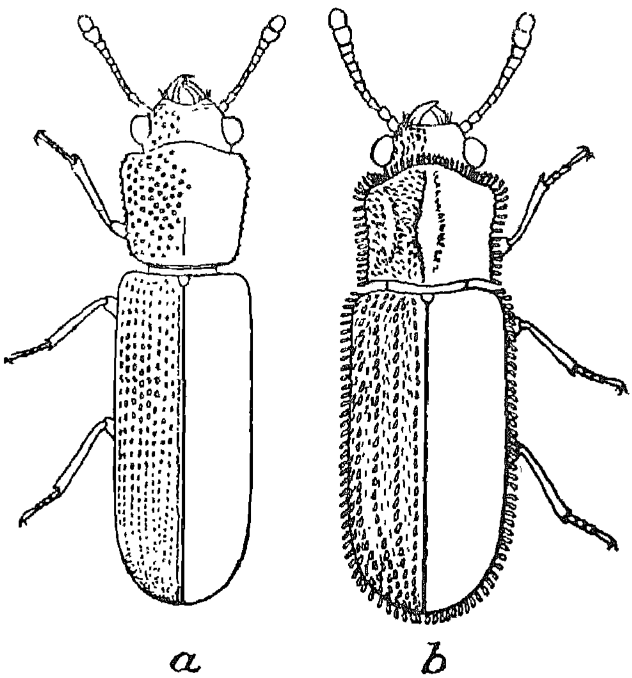


Fig. 20. *(a)* Beetle of *Lyctus africanus*, natural size 2 – 4·5 mm. *(b)* Beetle of *Minthea rugicollis*, natural size 1·8 – 3·5 mm.

Tokyo, p. 9) gives food-plants in Japan. Cann (1935, *Ind. For.* LXI, pp. 163-169) records *brunneus* in Indian timbers in England.

With regard to the habitat of *Lyctus brunneus* Lesne states (*tit. cit*, 1924, p. 84) "of all the lyctids this species is the most widely distributed over the surface of the globe. It is probable that man has played a preponderant role in its dissemination. To-day it exists at many points in the tropical and sub-tropical regions. Its great abundance and the continuity of its habitat in the Indo-malayan and Sino-japanese regions would seem to indicate that it originates from these countries." It is, however, not common in India, and our records of its presence are based mostly on timber yards in seaports and on factories inland where it is much less numerous than *Lyctus africanus* or *Minthea rugicollis*. We have not discovered it in regions characterised by low rainfall and a hot dry season or a true winter cold season although the species thrives in other parts of the world in such climates. Evidently it must be rated as a species of potential economic importance in India. So far it has been found attacking tea-chests in Ceylon, shooks used for rubber-chests and packing cases in south India,

plywood of *Dipterocarpus pilosus* and "champs" in north-east Assam, and in timbers exported from the Andamans to England. It is the largest of the Lyctus beetles and makes the largest tunnels and holes.

The emergence-period in north India shows April to June (maximum in April) as the months of greatest abundance with stragglers appearing until November; the maximum period elapsing before emergence is two and a half years. Lesne (1924, *tit. cit.* p. 85) notes that wood from Tonkin yielded *L. brunneus* at Paris for several years with emergence mainly in April-May. Its life-cycle in Japan, England and North America is annual and the present evidence points to an annual cycle in India with subsequent emergences of delayed individuals twice a year thereafter up to three years from first infestation.

There is an extensive literature on this species; the more important references to morphology, anatomy and biology are listed by Beeson and Bhatia, 1937, *Ind. For. Rec*, Ent., II, No. 12, pp. 277, 278, The larva, 5 mm., is described by Gardner, 1932, *Ind. For. Rec.*, XVIII, IX, p. 10, figs. 25-27.

For control measures see section on Powder-post Beetles.

Lyctus malayanus in *Mangifera indica, Terminalia belerica* and 'red pine'. This species may be a recent introduction to India as it occurs only in the Madras timber yards and Ceylon outside Malaya. The emergence-period is confined to the cold season with none at all in the dry hot weather and monsoon. It has been bred from planks used for tea chests in a factory at Moratuwa on the sea coast of Ceylon near Colombo but the emergence in this case took place throughout the year with peaks in June-July as well as in December-February.

Fig. 21. Damage to wood by Bostrychidae.

No. 1. Above left—*Balanites roxburghii* attacked by *Sinoxylon sudanicum*, showing larval galleries in cross-section and longitudinal section, penetrating to centre of branch.

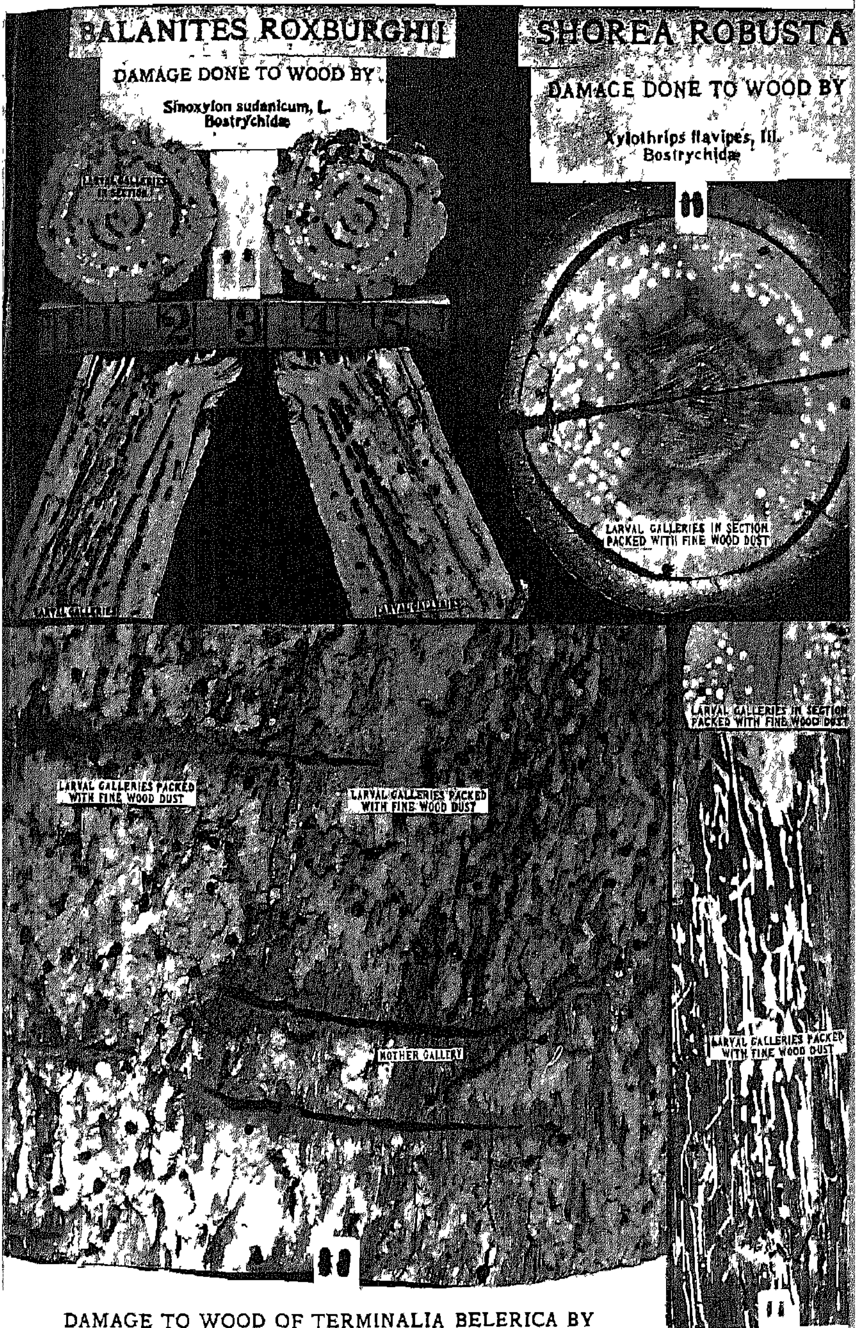
Note.—Most of the dust has fallen out of the galleries.

No. 2. Above right—*Shorea robusta* attacked by *Xylothrips flavipes*, showing larval tunnels in cross-section packed with wood-dust and confined to sapwood.

No. 3. Below right—*Shorea robusta* attacked by *Xylodectes ornatus*, showing, below, larval galleries running longitudinally on surface of sapwood and, above, the same in cross-section.

No. 4. Below left—*Terminalia belerica* attacked by *Sinoxylon crassum dekkanense*, showing larval galleries mostly running vertically, beetle galleries running horizontally and exit-holes in sapwood of log, most of the dust and destroyed wood has fallen away.

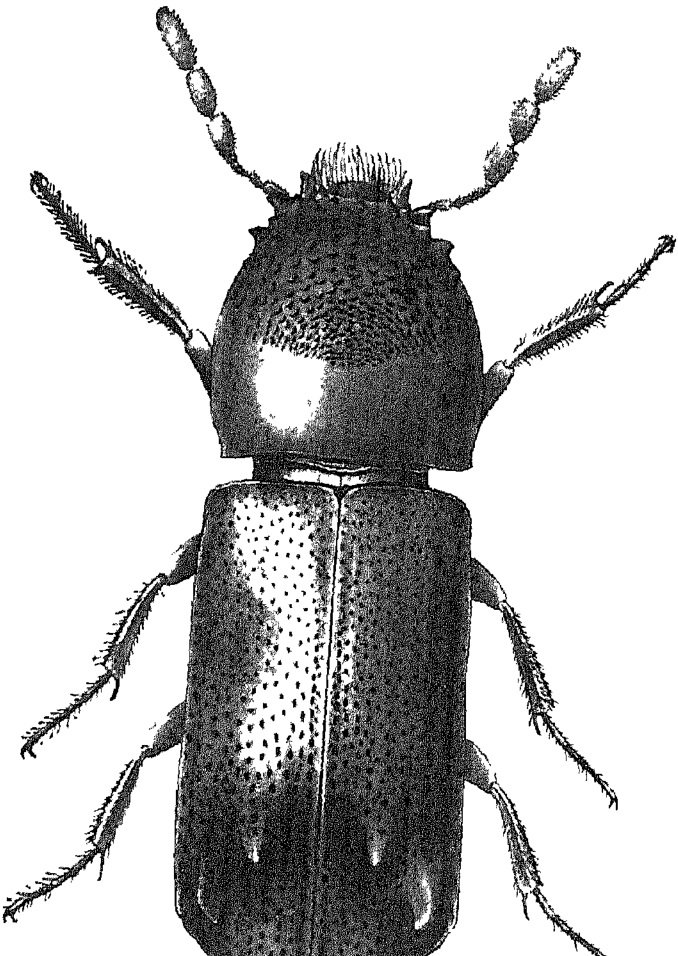
All material to the same scale indicated by inches on tape.



DAMAGE TO WOOD OF TERMINALIA BELERICA BY

Sinoxylon crassum, L
dekkanense, L
Bostrychidæ

DAMAGE DONE TO WO
BY
Xylodectes ornatus L
Bostrychidæ



Micrapate simplicipennis in *Bauhinia purpurea*, *Boswellia serrata*, *Bridelia stipularis*, *Cedrela toona*, *Elaeocarpus* sp., *Euphorbia pulcherrima*, *Ficus rumphii*, *Holarrhena antidysenterica*, *Indigofera tinctoria*, *Jatropha curcas*, *Lannea grandis*, *Mallotus philippinensis*, *Mangifera indica*, *Morus indica*, *Murraya koenigii*, *Trewia nudiflora*.

This species is a borer of small branchwood and twigs of trees as well as soft-wooded shrubs in north India and Burma. Emergence has been recorded from March to October with periods of greater abundance at the end of March, end of June and end of August, which may indicate three generations in the year with a hot weather life-cycle of three months and a monsoon life-cycle as short as two months. But a large portion of the larval brood of the spring oviposition has a more prolonged period of development resulting in two generations on the average. Emergence delayed for over twelve months may also occur. The larva, 5 mm., is described and figured by Gardner, 1933, *Ind. For. Rec.*, XVIII, ix, p. 16, pl. IV, fig. 58.

Minthea rugicollis

Adenanthera pavonina, *Amoora wallichii*, *Anogeissus acuminata*, *Artocarpus* sp., *Bombax malabaricum*, *Canarium euphyllum*, Cane, *Dendrocalamus strictus*, *Dipterocarpus tuberculatus*, *Dipterocarpus turbinatus*, *Derris elliptica*, *Erythrina indica*, *Garuga pinnata*, *Hardwickia pinnata*, *Helicia* sp., *Kydia calycina*, *Mangifera indica*, *Millettia pendula*, *Parashorea stellata*, *Parishia insignis*, *Phyllanthus emblica*, *Poinciana elata*, *Pterocarpus indicus*, *Shorea argentea*, *Sterculia campanulata*, *Swietenia mahagoni*, *Terminalia belerica*, *Terminalia bialata*, *Terminalia myriocarpa*, *Terminalia tomentosa*, *Thespesia populnea*, *Wrightia tinctoria*.

Kalshoven (1923, *Zool. Bijdragen*, XVI, p. 729) gives a list of timbers attacked by *Minthea* and *Lyctus* in Java. De Mesa, (1934, *Makiling Echo*, XIII, p. 245; 1935, *tit. cit.*, XIV, p. 93) lists 20 species attacked by it in the Philippines. Browne (1938, *Malayan Forester*, VII, pp. 107–120) records 93 species attacked by it in Malaya of which the very susceptible species are *Afzelia bakeri*, *Artocarpus* sp., *Avicennia alba*, *A. officinalis*, *Bombax larutensis*, *Helicia* sp., *Koompassia malaccensis*, *Parashorea lucida*, *Shorea faguetiana*, *S. hopeifolia*, *S. resina-negra*. The average diameter of the ovipositor of *M. rugicollis* is 54 microns and the limiting diameter of the wood-vessels in which eggs can be inserted is about 80 microns but timbers with vessels up to 90 microns can be considered fairly safe (Browne).

E c o n o m i c i m p o r t a n c e: *M. rugicollis* [see fig. 20*b* for the beetle] is subcosmopolitan in the tropics. In India it is

Fig. 22. Beetle of ***Xylothrips flavipes***, Bostrychidae; the natural size is shown by the small figure.

commonest in regions of high rainfall especially in south India and Burma and locally replaces *Lyctus africanus* characteristic of the northern and drier regions. In the Andamans it is the predominant species of the timber-mills. It occurs in plywood and match factories in Assam and Bombay and has been reared from I. P. wooden tent-pins in ordnance depots and from ships' dunnage (sticks) in Rangoon docks. It occurs in factories making tea-chests in Ceylon.

Kalshoven (1923, *Zool. Bijdragen*, XVI, pp. 718–740, fig. 58; and 1923, *De Thee*, IV, pp. 17, pl.) records and illustrates damage done by this species in plywood tea-chests in Java. When working in plywood *M. rugicollis* tends to make galleries on the outer surface of panels in contact and more extensively than do other species of lyctids. It also bores a tunnel when mature, directly at right angles to the sheets of veneer, penetrating several panels. It also bores lead or tinfoil linings of tea-chests.

Browne (1938) states it is the dominant powder-post beetle of Malaya attacking sapwood of many species of fallen trees and girdled trees in the forest and occurring in all sawmills and timber yards.

Life-history

The newly emerged beetles are active, taking short flights to find fresh breeding-material, but thereafter they fly less readily and shun light. Pairing may occur immediately after emergence and is repeated frequently throughout life. Beetles live for as many as 60 days (females) and 110 days (males). Oviposition follows a few days after pairing and the egg is inserted in a pore of the wood. The larval tunnel is long and irregular but mainly follows the grain of the wood. Dust is not ejected until at a late stage in the life-cycle and is generally a sign that immature beetles are working. The average progeny of one female is about 40 of which 45 percent are females, and the potential increase in a year may be over six thousand individuals (Browne).

Life-cycle: In the equatorial climate of Malaya the minimum duration of the life-cycle at temperatures between 71° and 93° F. is about 11 weeks (incubation-period about one week; larval period 7 weeks; pupal and prepupal periods about 12 days; immature beetles 5 days; pairing to oviposition 4 days). At the average rate of development in fully nutritious wood the total life-cycle takes about 130 days, allowing a sequence of 3 generations a year with the peaks of most abundant emergence in April, in August and in November, December. At the minimum rate of development 4 generations a year are possible (Browne).

In north India beetles may leave infested wood at any time in the year but there are two periods marked by increased abundance of emerging beetles: May and June with 7 percent and 10 percent respectively, and October–December with 14 percent, 21 percent

and 16 percent respectively of the annual population. There may be more than two generations a year in favourable climates but the pronounced postmonsoon and cold season emergence and its cessation in the dry spring indicates that the moisture-content of the wood, as determined by atmospheric humidity, is the most important factor after starch-content. Wood attacked by *M. rugicollis* may yield beetles for over five years.

The larva, 3 mm., is described and figured by Gardner (1933, *Ind. For. Rec.*, XVIII, ix, p. 12, pl. ii, fig. 24). All stages are figured by Browne, 1938.

For control measures see the section on Bostrychidae, Powder-post beetles.

LITERATURE:

Browne F. G., 1938, *Malayan Forester*, VII, pp. 107-120, figs. 3. The common Malayan powder-post beetle, Minthea rugicollis.

Octodesmus minutissimus in *Acacia* sp., *Albizzia lebbek*, *Albizzia odoratissima*, *Caesalpinia sepiaria*, *Flemingia congesta*, *Mallotus philippinensis*. Occurs in the Peninsula and north India. Emergence in April to October.

Parabostrychus acuticollis in *Mallotus philippinensis*, *Tephrosia candida*.

Parabostrychus elongatus in *Mangifera indica*.

Phonapate fimbriata in *Calycopteris floribunda*.

Phonapate frontalis in *Phoenix dactylifera*.

Phonapate stridula in *Dendrocalamus strictus*.

Rhizopertha dominica.

This species is a cosmopolitan pest of stored grain of all kinds and the flour of the same (wheat, barley, rice, maize, millet, sorghum, juar, etc.) and starchy food-substances generally (dried potatoes, manioc, roots, waternuts, biscuits, etc.). Also from caged logs of:—*Abies webbiana*, *Alnus nitida*, *Artocarpus hirsuta*, bamboo, *Bauhinia variegata*, *Buchanania latifolia*, *Dalbergia sissoo*, *Dendrocalamus strictus*, *Garuga pinnata*, pith, *Hertiera fomes*, *Mallotus philippinensis*, *Shorea robusta*, *Sterculia campanulata*, *Terminalia tomentosa*, *Thespesia populnea*.

Most of these cases are based on beetles sheltering in the bark or in tunnels of other borers but in some they had undoubtedly developed as larvae. A large form with exceptionally strongly developed granulation of the elytral declivity was bred from *Shorea robusta* and labelled *R. dominica granulipennis* by Lesne. Potter (1935) considers that *R. dominica* originally fed solely on wood, probably living wood and records an experiment in which attack was induced on a living maize plant. We have never found *R. dominica* boring in living plants. The species occurs throughout India, Burma and Ceylon and is carried to high elevations in the mountains along trade routes.

There are four larval stages and a prepupa. The latest des-

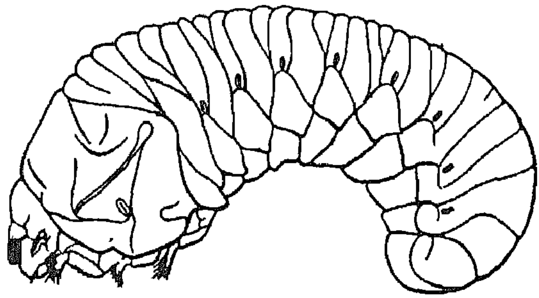


Fig. 23. Larva of *Schistoceros anobioides*, natural size 15 mm.

criptions and figures of the egg, pupa and adult morphology are by Gardner (1933, *Ind. For. Rec.*, XVIII, IX, p. 6, pl. III, figs. 32-36) and Potter (1935).

Life-history: The life-history in wheat has been studied by several investigators, and in India by Barnes, Grove, Fletcher and Ghosh. The first two authors (1916, *Mem. Agr. Res. Inst. Pusa, Chem.*, IV, p. 191) put the number of generations per annum in the Punjab as probably five of which four vary from 28 to 41 days and that during the winter lasts 183 days. In England Potter observed a life-cycle of 30 to 40 days at 30°C. and 30 per-cent relative humidity in wheat and maize. Adult beetles have been kept alive for ten months.

Life-history in wood: A piece of *Artocarpus hirsuta* from Mangalore caged in January yielded beetles of *R. dominica* in May to October of the same year, again in the second year, again in May in the third year, and in April of the fourth year.

Life-history in topi pith: The grain beetle is a pest of army pith helmets. The pith shapes for topis supplied by contractors are made of sliced pith pasted together with wheat flour paste. The beetles bore into the shapes while drying and before being covered with paper or cloth and varnished; they feed on and oviposit in the flour paste. After the topis are finished off and taken into stock in Ordnance Stores the borers mature and escape by cutting holes through the varnished layer and cloth topi cover. Infested pith hats have yielded beetles for two years.

In pith shapes made up with flour paste poisioned with copper sulphate (1 in 80) no larval development of *R. dominica* occurred although beetles bored into the pith. Beetles did not bore into cakes of flour paste boiled and poisoned with copper sulphate and allowed to harden. No oviposition occurred in similar cakes not allowed to harden. Beetles did not bore into pith shapes pasted with flour paste containing rotenone (1 in 200).

Schistoceros anobioides *in Anogeissus latifolia*, *Anogeissus*

pendula, Bassia latifolia, Bombax malabaricum, Buchanania latifolia, Cassia fistula, Dalbergia paniculata, Ficus hispida, Garuga pinnata, Holarrhena antidysenterica, Lagerstroemia tomentosa, Lannea grandis, Mallotus philippinensis, Mangifera indica, Shorea assamica, Shorea robusta, Psidium guava, Tectona grandis.

This species occurs throughout the Plains and Peninsula as a borer of poles and the sapwood of logs and converted timber. Although a common insect its broods are rarely as numerous in individuals as are those of the common species of *Heterobostrychus* and *Sinoxylon*. In fig. 13, No. 2 the characteristic appearance of the larval tunnels is shown in cross and longitudinal sections. The life-cycle is ordinarily annual, but occasionally, as for example in wooden tent-pins alternately stored in the dry and exposed to the weather, the life-cycle may last three years. Emergence occurs mainly between March and July with fifty percent of the annual population emerging in May and June.

The larva is described and figured by Gardner (1933, *Ind. For. Rec.*, XVIII, ix, p. 13). [see also text-figure 23].

Schistoceros malayanus *in Heritiera fomes.*

Sinoxylon anale.

Acacia arabica, Acacia catechu, Acacia gageana, Acacia modesta, Acrocarpus fraxinifolius, Adina cordifolia, Albizzia amara, Albizzia lebbek, Albizzia odoratissima, Albizzia procera, Albizzia stipulata, Anogeissus acuminata, A. latifolia, Bamboo, *Bombax malabaricum, Bombax insigne, Buchanania latifolia, Butea frondosa, Caesalpinia sepiaria, Calycopteris floribunda, Cassia fistula, Cassia siamea, Castanea vesca, Castanopsis argyrophylla, Casuarina equisetifolia, Cedrela toona, Combretum ovalifolium, Cordia myxa, Dalbergia latifolia, Dalbergia sissoo, Dendrocalamus strictus, Derris elliptica, Dipterocarpus tuberculatus, Eucalyptus citriodora, Eugenia jambolana, Ficus glomerata, Ficus religiosa, Fluggea microcarpa, Gmelina arborea, Grevillea robusta, Grewia tiliaefolia, Indigofera tinctoria, Lagerstroemia lanceolata, Lannea grandis, Mallotus philippinensis, Mallotus roxburghianus, Mangifera indica, Melia azedarach, Millettia brandisiana, Morus indica, Ougeinia dalbergioides, Parashorea stellata, Pongamia glabra, Prosopis juliflora, Prosopis spicigera, Pterocarpus indicus, Pterocarpus marsupium, Quercus lamellosa, Quercus* sp., *Shorea robusta, Sterculia ornata, Tectona grandis, Terminalia arjuna, Terminalia belerica, Terminalia bialata, Terminalia tomentosa, Xylia dolabriformis, Zizyphus jujuba, Zizyphus rugosa, Zizyphus xylopyra.*

Widely distributed in the Oriental Region and introduced in Indian goods to Australia and New Zealand.

E c o n o m i c i m p o r t a n c e : This species is the commonest bostrychid in India and is found as frequently within the forest

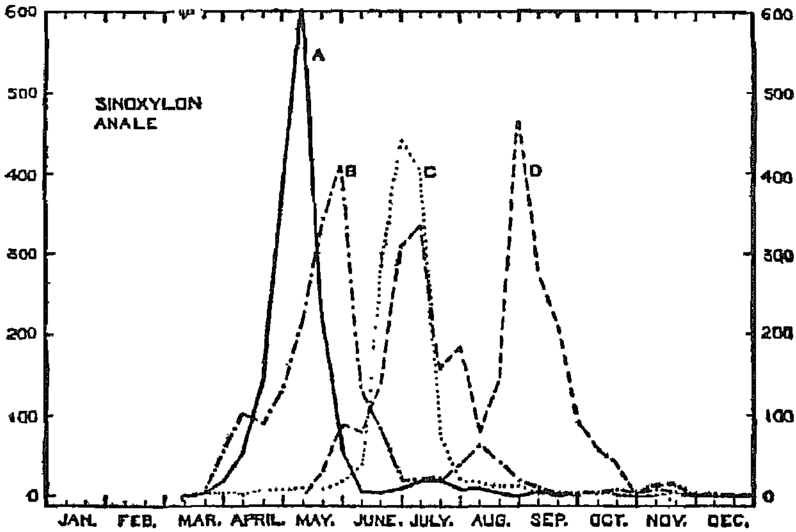


Fig. 24. Emergence-period of *Sinoxylon anale.* Numbers of beetles emerging at intervals of one third of a month. Four separate graphs A, B, C and D showing peaks of three separate broods. The graphs of emergence show a selection of infestations grouped according to the times of caging and illustrate the variation in the occurence of the peaks of maximum abundance; these peaks do not appear to be correlated with seasonal weather conditions or with generations. They are due to nutritional conditions and density of infestation. Where the density of the initial infestation is appropriate to the volume of the wood, and the wood offers most favourable food and moisture-content, rapid development of larvae and immature beetles results. Where the density of infestation is excessive, the wood is over-populated and there is competition for nourishment; the majority of the larval population is forced to tunnel over longer distances in search of untouched food-supplies and to ingest larger quantities of less nutritious frass; the immature beetles meet with the same difficulties and slower development results.

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as in timber depots, sawmills and factories. It is primarily a borer of the sapwood of logs particularly of Leguminosae but its range of food-plants is wide and varied. In timbers with well-defined line of separation between sapwood and heartwood the larval galleries do not penetrate the true heart; the sapwood may be entirely reduced to dust.

It is recorded as injurious to wooden tent-pins of various woods in the Ordnance stores in arsenals; in the sapwood of timbers

used in building construction; in boxes and packing cases of planks but not of plywood.

System of tunnels: The gallery-system of *S. anale* in a log starts with a short entrance tunnel bored radially through the bark in to the inner sapwood, and then turns and runs in the same plane in a curve parallel to the outer sapwood circumference. It is used as an oviposition tunnel and is cleaned of all the wood-dust produced by the parent beetles during its excavation; both male and female occupy it while the eggs are laid from time to time in niches in the walls and they remain long after hatching is complete, guarding the tunnel against entry of predators and parasites. The larvae bore ever-widening larval galleries which run upwards and downwards in the sapwood for several inches, more or less straight but sometimes intersecting; they are circular in cross-section and tightly packed with fine wood-dust. Pupation takes place at the extreme end of the larval tunnel in a cell and the beetle bores out by a direct route to the surface. Fig. 15, No. 1 shows oviposition tunnels of the beetle, larval tunnels and exit-holes.

The adult beetles [fig. 4, No. 59] sometimes bore into green shoots and twigs for the purpose of feeding or hibernation making axial tunnels; as a result the leaders of seedlings or young saplings may be girdled or killed. Beetles bore into the stems of sickly or dying poles with more or less success. Horizontal tunnels are made just within the circumference of the cambium layer and these fill with a black gum that exudes from the entrance-hole and runs down the bark. Other insects sampling sickly shisham poles have been observed to produce the same conspicuous symptoms. On account of the exudation of gum the borers do not remain to lay eggs.

Life-cycle: The life-cycle varies between very wide limits; its minimum may be round about 3 months and the maximum recorded in the Dehra Dun insectary is over 4 years. *S. anale* emerges as adult beetle throughout the year, and there is no regular sequence of generations and no regular correlation between the length of the life-cycle and the season of the year. The following cases illustrate the variation in the rate of emergence of the annual population.

(*a*) *Dalbergia sissoo* caged the previous October; emergence by the end of April 37 percent, by the end of May 97 percent.

(*b*) *Dalbergia sissoo* caged in February; emergence by the end of May 3 percent, end of June 59 percent, end of July 96 percent.

(*c*) *Acacia arabica* caged in May; emergence by the end of July 28 percent, end of August 61 percent, end of September 94 percent (percentages calculated on the total emerging during one year, not the total population in the wood).

The proportion of the individuals of an original infestation carrying over from the first year to the second or subsequent years is, in the case of *S. anale*, not very high; emergence in subsequent years is usually less than that of the first year.

A generation of *S. anale* may start with oviposition on any date in the year (except possibly in the two or three coldest months in the north of India) and the life-cycle of individuals hatching from eggs of the same date may be completed in as little as two and halt months or may require over a year.

[See fig. 24 for graphs of the emergence-period.]

LITERATURE:
Beeson and Bhatia B. M., 1937, *Ind. For. Rec.*, Ent., II, No. 12, pp. 285-289, fig. 14.
Gardner J. C. M., 1933, *Ind. For. Rec.*, Ent. XVIII, ix, p. 18.
Garthwaite P. F., 1940, *A guide to the borers of commercial timber in Burma.*

Sinoxylon atratum.

(a) subspecies **atratum.**

Acacia catechu, Artocarpus hirsuta, Casuarina equisetifolia, Combretum ovalifolium, Hopea parviflora, Lagerstroemia lanceolata, Mallotus alba, Mallotus philippinensis, Phyllanthus emblica, Pongamia glabra, Santalum album, Terminalia arjuna, Terminalia paniculata, Thespesia populnea, Trewia nudiflora.

The subspecies *atratum atratum* occurs in the Peninsula and south India. From caged material emergences occurred in May to September. It is one of the bostrychids that bore into living saplings or advanced seedlings of *Santalum album* (in Salem, Madras) making an axial tunnel and causing the upper part of the plant to die back. It is also one of the borers of dying saplings of *Artocarpus hirsuta* (South Mangalore). The life-cycle appears to be repeated twice a year but the evidence is insufficient.

The larva is described and figured by Gardner, 1933, *Ind. For. Rec.*, XVIII, ix, p. 18, pl. iii, figs. 38, 39.

(b) subspecies **kohlarianum.**

Acacia gageana, Anogeissus latifolia, Cassia siamea, Combretum decandrum, Lagerstroemia parviflora, Mallotus philippinensis, Mangifera indica, Millettia auriculata, Moringa pterygosperma, Shorea robusta, Terminalia belerica, Vallaris heynei and unidentified timbers.

The subspecies *atratum kohlarianum* which occurs north of the river Ganges and in dry regions of the east Peninsula has been bred in June to October with the maximum emergence in June; the life-cycle appears to be annual. It was observed attacking poles and coppice of *Shorea robusta* which were dying from unascertained causes in the cold weather.

Sinoxylon beesoni in *Wendlandia tinctoria* in Burma.

Sinoxylon capillatum.

Acacia catechu, A. gageana, Acacia modesta, Albizzia lebbek, Albizzia procera, Bauhinia purpurea, Bombax malabaricum, Cedrela toona, Dalbergia sissoo, Ficus palmata, Mallotus philippinensis, Millettia auriculata, Morus indica, Prosopis juliflora,

Pterocarpus marsupium, Shorea robusta, Terminalia belerica, Terminalia tomentosa, and miscellaneous timbers.

A species of north India which breeds mainly in small branch wood and twigs. The life-cycle is annual with a sharply limited emergence-period in May to July; over fifty percent of the generation emerges in the middle third of May; a few belated individuals may emerge in the cold months. The beetles bore into slender twigs and make long tunnels which are mainly for the purpose of feeding and shelter; such tunnels are occupied for long periods.

The larva is described by Gardner, 1933, *Ind. For. Rec.*, XVIII, ix, p. 18.

Sinoxylon circuitum in *Acacia* sp., *Mallotus philippinensis.*

Sinoxylon conigerum in *Adina cordifolia, Albizzia amara, Bombax malabaricum, Ficus altissima, Grewia tiliaefolia, Holoptelea integrifolia, Mangifera indica, Shorea robusta, Terminalia bialata, Terminalia myriocarpa* and unidentified climbers.

Of wide distribution but not common in India and recorded only from the wet warm regions. Isolated individuals have been collected in every month of the year (except April). There are a few cases of damage by this species to ornamental timbers, e.g., *Terminalia bialata* (imported to Bombay from Andamans), and *Terminalia myriocarpa* (Calcutta timber yards). It is also recorded to damage lead cables in Hawaii.

Sinoxylon crassum.

According to Lesne this species shows two well marked races one of which, the typical form, occurs in Indo-China and Burma and the sub-Himalayan region, and the other in Central and Southern India. [fig. 4, No. 58, beetle natural size]

The geographical distribution of the two morphological forms is however not sharply defined and in some localities broods may be reared from the same piece of wood which are 100 percent pure or consist of both forms, for example: at North Dangs, Surat, Bombay 99 percent dekkanense; at North Sihawa, Raipur, C. P. 50 percent dekkanense; in the neighbourhood of Dehra Dun nearly 100 percent crassum; Burma 100 percent crassum.

(a) subspecies **crassum**

Acacia catechu, Acacia gageana, Acacia modesta, Adina cordifolia, Albizzia mollis, A. moluccana, Albizzia odoratissima, Albizzia procera, Anogeissus latifolia, Bauhinia vahlii, Bombax insigne, Butea frondosa, Caesalpinia sepiaria, Cassia fistula, Cassia siamea, Castanea vesca, Combretum decandrum, Dalbergia oliveri, Dalbergia paniculata, Dalbergia sissoo, Dendrocalamus strictus, Dipterocarpus tuberculatus, Ficus glomerata, Gmelina arborea, Mallotus philippinensis, Mangifera indica, Millettia auriculata, Pinus longifolia, Prosopis spicigera, Pterocarpus marsupium, Shorea robusta, Terminalia arjuna, Terminalia bele-

rica, Terminalia chebula, Terminalia tomentosa, Vallaris heynei, Wendlandia tinctoria.

Beetles emerge from caged wood continuously throughout a twelve months period and into the second year. At the quickest possible rate of development there might be a series of four life-cycles in one year in the warmest parts of India where no true cold weather season intervenes. But normally the quickest rate of development is attained by only a small proportion of the population arising from each brood of eggs, the majority developing more slowly and taking periods equivalent to two and three or more short life-cycles. This slowing down of the rate of growth is apparently due to differential nutrition in the larval and immature beetle stages as well as to delay in pairing and ovipositing in the free adult stage.

The form *crassum crassum* has a first generation beginning in the first six weeks of the year (as for *crassum dekkanense*, see below), or as late as April in north east Assam and north Burma. The emergence-graphs show peaks of maximum abundance from the end of May to the end of June with a subsidiary period of greater relative abundance in December, which may indicate periods at which the oviposition of a second and a third generation could occur.

Economic importance: A common borer of the sapwood of logs particularly of Leguminosae. In timbers with a well defined line of separation between sapwood and heartwood the larval galleries of *S. crassum* do not penetrate the heartwood although the sapwood may be entirely reduced to dust. Many woody climbers are attacked by this species shortly after they are cut, and when climber cutting preceeds fellings or thinnings the borers bred in the climbers pass on to the felled logs.

It is a borer of dying poles and saplings, of, e. g., *Shorea robusta* (United Provinces) and also of the green shoots of young saplings and coppice; the latter form of damage is probably in the nature of a starvation-attack resulting from excessive breeding in felling-refuse.

(b) subspecies **dekkanense**

Acacia catechu, Aegle marmelos, Albizzia procera, Anogeissus latifolia, Bombax malabaricum, Buchanania latifolia, Calycopteris floribunda, Cassia fistula, Casuarina equisetifolia, Dalbergia latifolia, Dalbergia paniculata, Dalbergia sissoo, Lagerstroemia parviflora, Lannea grandis, Mangifera indica, Ougeinia dalbergioides, Prosopis spicigera, Pterocarpus marsupium, Sapium sebiferum, Shorea robusta, Tectona grandis, Terminalia arjuna, Terminalia belerica, Terminalia chebula, Terminalia tomentosa, Zizyphus xylopyra.

Life-cycle: During the cold weather months beetles emerge irregularly from infested wood or from hibernating tunnels

in branches and twigs. The time elapsing before these individuals pair and oviposit varies much with the weather but it usually occurs early in the year. The minimum life-cycle for the first generation may be about eleven weeks, but as much as seven months may elapse before a beetle derived from a cold season egg matures and emerges. In regions where there is a definite winter season, e.g., in the Indus plains, the first generation beetles do not lay eggs until April.

Data are not available to show that beetles on the wing in the hot weather oviposit at once and give rise to a second generation during the monsoon but it may be presumed that some do so.

From material caged in October beetles emerge in irregular numbers during the period November to February. According to the Divisional Foreet Officer, Sukkur, *Prosopis spicigera* cut during the month of September is immune from attack by *dekkanense,* while that cut during the succeeding cold weather months is less liable to damage than that felled after March.

Economic importance: The borer is a regular pest of logs and split wood used for fuel particularly, for example, of *Prosopis spicigera* in Sind and in the Punjab where contractors' stocks kept on hand for more than a year depreciate considerably and the smaller billets are reduced to dust. *Dalbergia sissoo* and *Acacia modesta* fuel in the irrigated plantations of the Punjab is similarly destroyed.

Damage by *crassum dekkanense* was reported in the North Western Railway Workshops, Lahore (*Albizzia procera* and *Terminalia belerica*); to wooden tent-pins in the Ordance Department stores at Ferozepore and Rawalpindi, Punjab; to the sapwood of *Tectona grandis* and *Terminalia tomentosa* used for buildings at Seoni, C. P.; to *Bombax malabaricum* cut for planking in Bahraich division, U. P., etc.

Sinoxylon cucumella in *Tectona grandis* and *Wendlandia tinctoria.*

Sinoxylon dichroum in *Mallotus philippinensis* and other species.

Sinoxylon indicum in *Acacia catechu, Adina cordifolia, Anogeissus latifolia, Buchanania latifolia, Cassia siamea, Dalbergia sissoo, Mangifera indica, Prosopis spicigera, Pterocarpus marsupium, Zizyphus xylopyra.*

A borer of fuel wood and military wooden tent-pins.

Sinoxylon lycturum in *Bambusa polymorpha* in Burma.

Sinoxylon marseuli convexicauda in *Cynometra polyandra* in Assam, Bengal.

Sinoxylon oleare in *Acacia gageana, Bauhinia purpurea, Caesalpinia sepiaria, Dalbergia sissoo, Mallotus philippinensis, Mangifera indica, Millettia auriculata, Pterocarpus marsupium, Terminalia chebula* and species of climbers.

The species is primarily a borer of small branchwood and

rica, Terminalia chebula, Terminalia tomentosa, Vallaris heynei, Wendlandia tinctoria.

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It is a borer of dying poles and saplings, of, e. g., *Shorea robusta* (United Provinces) and also of the green shoots of young saplings and coppice; the latter form of damage is probably in the nature of a starvation-attack resulting from excessive breeding in felling-refuse.

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E c o n o m i c i m p o r t a n c e: The borer is a regular pest of logs and split wood used for fuel particularly, for example, of *Prosopis spicigera* in Sind and in the Punjab where contractors' stocks kept on hand for more than a year depreciate considerably and the smaller billets are reduced to dust. *Dalbergia sissoo* and *Acacia modesta* fuel in the irrigated plantations of the Punjab is similarly destroyed.

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Sinoxylon cucumella in *Tectona grandis* and *Wendlandia tinctoria*.

Sinoxylon dichroum in *Mallotus philippinensis* and other species.

Sinoxylon indicum in *Acacia catechu*, *Adina cordifolia*, *Anogeissus latifolia*, *Buchanania latifolia*, *Cassia siamea*, *Dalbergia sissoo*, *Mangifera indica*, *Prosopis spicigera*, *Pterocarpus marsupium*, *Zizyphus xylopyra*.

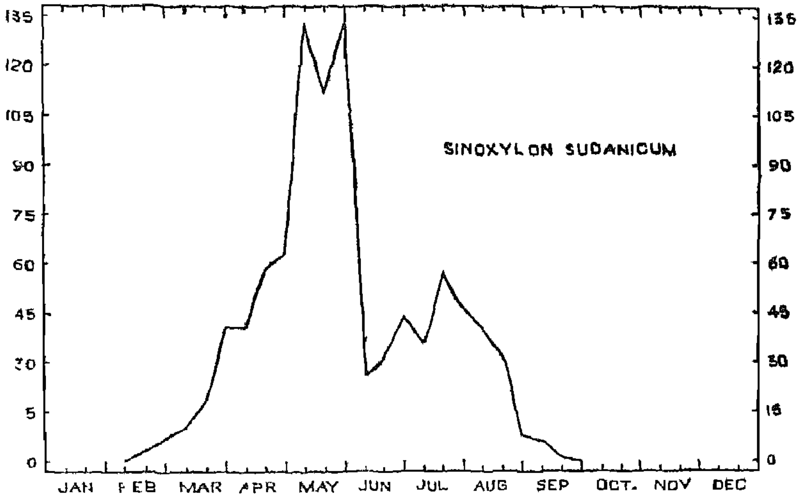
A borer of fuel wood and military wooden tent-pins.

Sinoxylon lycturum in *Bambusa polymorpha* in Burma.

Sinoxylon marseuli convexicauda in *Cynometra polyandra* in Assam, Bengal.

Sinoxylon oleare in *Acacia gageana*, *Bauhinia purpurea*, *Caesalpinia sepiaria*, *Dalbergia sissoo*, *Mallotus philippinensis*, *Mangifera indica*, *Millettia auriculata*, *Pterocarpus marsupium*, *Terminalia chebula* and species of climbers.

The species is primarily a borer of small branchwood and



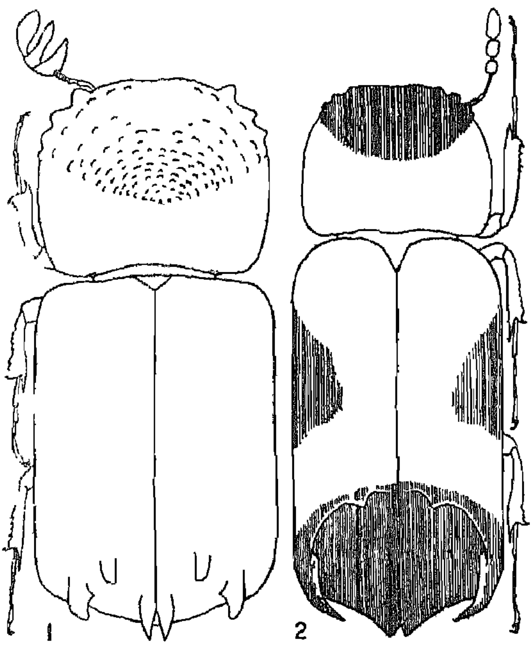


Fig 25. Above—Emergence-period of *Sinoxylon sudanicum* at Dehra Dun; numbers of beetles emerging at intervals of one third of a month.

Below—No. 1, *Sinoxylon pugnax*, 6-9 mm.
No. 2, *Xylodectes ornatus*, 3-6 mm.

climbers. The emergence period extends from June to September with greatest abundance in July, apparently in response to the establishment of the monsoon. The characters of the larva are given by Gardner (1933) *Ind. For. Rec.*, XVIII, IX, p. 18, pl. iii, fig. 40.

Sinoxylon pachyodon in *Cynometra polyandra* and unidentified timbers.

Sinoxylon parviclava in *Tectona grandis* in Burma.

Sinoxylon pubens in *Dalbergia paniculata* in south India.

Sinoxylon pugnax in *Acacia modesta* and *Albizzia procera* and in wood used for military tent-pins in Ordnance stores and in timber for railway workshops in the Punjab.

Sinoxylon pygmaeum in *Acacia gageana, Albizzia procera, Caesalpinia sepiaria, Combretum decandrum, Dalbergia latifolia, Ficus bengalensis, Mallotus philippinensis, Mangifera indica, Millettia auriculata, Shorea robusta, Terminalia belerica.* A small species occurring in dry branches and stems throughout India and active all the year round.

Sinoxylon sudanicum in *Acacia arabica, Acacia gageana, Albizzia lebbek, Albizzia procera, Balanites roxburghii*, Bamboo, *Butea frondosa, Casuarina equisetifolia, Dalbergia sissoo, Ficus palmata, Mallotus philippinensis, Mangifera indica, Pongamia glabra, Prosopis spicigera, Quercus* sp., *Rhus parviflora, Shorea robusta, Terminalia tomentosa*, and several unindentified woods.

Life-cycle: Beetles of this species have been bred in every month of the year as the emergence-period is prolonged. Fig. 25 shows an emergence graph from *Balanites roxburghii* in which 40 percent of the population of the year emerged in May and 43 percent in the three months April, June and July ; there is a subsidiary peak at the end of July. Other emergence records show the times of greatest swarming within the period August–October which suggest that the life-cycle is ordinarily prolonged and not repeated more than twice a year. The tendency to carry over to the following year is marked and the maximum period recorded between caging and emergence is four years in wooden tent-pins.

Economic importance: The species is frequently found in company with *S. anale* or *S. crassum* in timber but is not so abundant and is of more restricted distribution. It is a borer of wooden tent-pins in the Ordnance Department stores. The adult sometimes makes a tunnel in small stems and twigs of saplings for feeding purposes ; it is also one of the borers of dying poles. The larva is described and figured by Gardner (1933, *Ind. For. Rec.*, XVIII, ix, p. 18, pl. iii, fig. 37).

Sinoxylon tignarium in Bamboo, *Mallotus roxburghianus, Terminalia myriocarpa* in Assam, Bengal.

Stephanopachys himalayanus bores rambling galleries in the thick outer bark of *Pinus longifolia*.

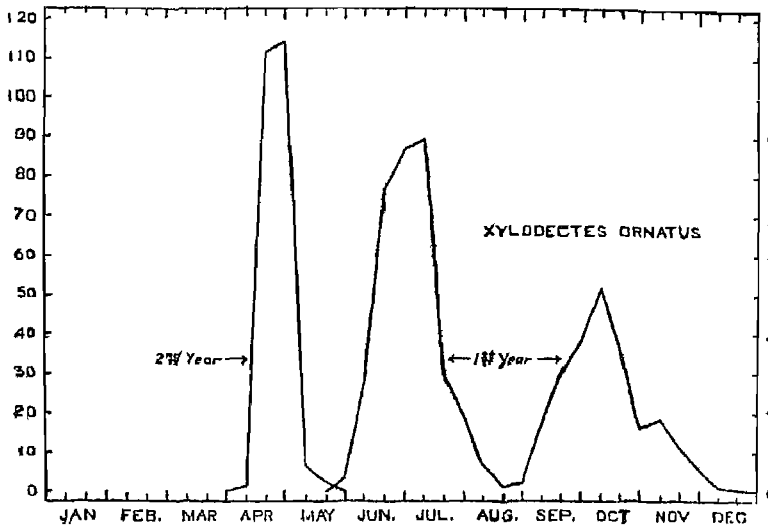


Fig. 26. Emergence-period of *Xylodectes ornatus*. Numbers of beetles emerging at intervals of one third of a month, showing peaks of emergence of 3 successive generations.

Trogoxylon auriculatum in *Acacia gageana*, *Acacia intsia*, *Acacia modesta*, *Acacia* sp., *Albizzia lebbek*, *Albizzia odoratissima*, Bamboo, *Bauhinia retusa*, *Cassia siamea*, *Cinnamomum inunctum*, *Combretum decandrum*, *Dalbergia sissoo*, *Dalbergia* sp., *Dendrocalamus strictus*, *Erythrina suberosa*, *Garuga pinnata*, *Kydia calycina*, *Mallotus philippinensis*, *Prosopis spicigera*, *Shorea robusta*, and unidentified woods.

T. auriculatum is a forest-inhabiting species breeding in dry wood and not ordinarily present in sawmills and wood factories in India. It has been reared from wooden I. P. tent-pins stored in the Madras and Rawalpindi Ordnance depots but the locality of infection of this material is obscure.

It has a much more sharply defined emergence-period than its allied lyctids; about half the annual population emerges in May, a quarter in June and the remainder in July to October; there is no emergence during the cold season. The life-cycle is considered to be annual. Attacked material may continue to yield beetles for four years, the emergence of subsequent years often exceeding that of the first year. The larva is described by Gardner, 1933, *Ind. For. Rec.*, XVIII, ix, p. 9, pl. ii, figs. 21-23.

Trogoxylon spinifrons in *Acacia gageana*, *Acacia modesta*, *Alstonia scholaris*, *Anogeissus latifolia*, Bamboo, *Bombax malabaricum*, *Boswellia serrata*, *Buchanania latifolia*, *Canarium strictum*, *Careya arborea*, *Casuarina equisetifolia*, *Cedrela toona*, *Clerodendron infortunatum*, *Dalbergia paniculata*, *Dalbergia sissoo*,

Dendrocalamus strictus, Dipterocarpus turbinatus, Garuga pinnata, Lannea grandis, Litsaea kingii, Litsaea zeylanica, Machilus odoratissima, Mallotus philippinensis, Mangifera indica, Phoebe lanceolata, Phyllanthus emblica, Pithecolobium dulce, Prosopis juliflora, Pueraria tuberosa, Red pine, *Semecarpus anacardium, Shorea robusta, Soymida febrifuga, Spondias mangifera, Sterculia alata, Sterculia campanulata, Terminalia belerica, Terminalia tomentosa, Xylia xylocarpa*, and unidentified wood.

T. spinifrons has been recorded from planking and other converted timber as well as from wooden tent-pegs, dry sticks, bamboo and logs. It is not so common as *Lyctus africanus*, but in some localities, as for example, the timber yards in Calcutta, it may replace the latter species almost completely in some years. It also occurs at higher elevations. Emergence occurs throughout the year but the life-cycle is apparently repeated twice with peak emergences in June-July (which months yield 26 percent) and in October-November (which months yield 45 percent of the annual population). In exhibiting a well sustained emergence during the postmonsoon and cold seasons it resembles *Lyctoxylon japonum* and *Minthea rugicollis* rather than its congener *Trogoxylon auriculatum*. The longest period elapsing between the date of caging and the first emergence is eleven months and the longest period during which beetles have continued to emerge from a piece of attacked wood is five years.

Xylion bifer in *Cordia myxa* and *Tectona grandis* in south India and Burma.

Xylocis tortilicornis in *Amoora wallichii, Berberis aristata, Bombax malabaricum, Caesalpinia sepiaria, Celtis australis, Colebrookia oppositifolia, Cordia myxa, Eugenia jambolana, Flemingia congesta, Flueggia microcarpa, Mallotus philippinensis, Pongamia glabra, Pterocarpus marsupium, Quercus* sp., *Santalum album, Shorea robusta, Swietenia mahagoni, Tectona grandis, Terminalia tomentosa, Thespesia populnea, Zizyphus xylopyra.*

This species breeds mainly in small stuff, dead branches, etc., but also in the sapwood of logs throughout India and Ceylon. There are two complete life-cycles in a year with fairly sharply marked emergence-periods, one of which overwinters and emerges in April-June (with about 80 percent of the generation emerging in May) and the other of which emerges in July to September (with about 50 percent of the generation emerging in August,) This hot weather life-cycle may be completed in three months. Individuals of belated development may take two or three years to mature.

Xylodectes ornatus.

Acacia catechu, Acacia gageana, Albizzia procera, Albizzia stipulata, Bauhinia retusa, Bauhinia vahlii, Bauhinia variegata, Bombax malabaricum, Butea frondosa, Caesalpinia sepiaria, Calycopteris floribunda, Castanea vesca, Castanopsis tribuloides,

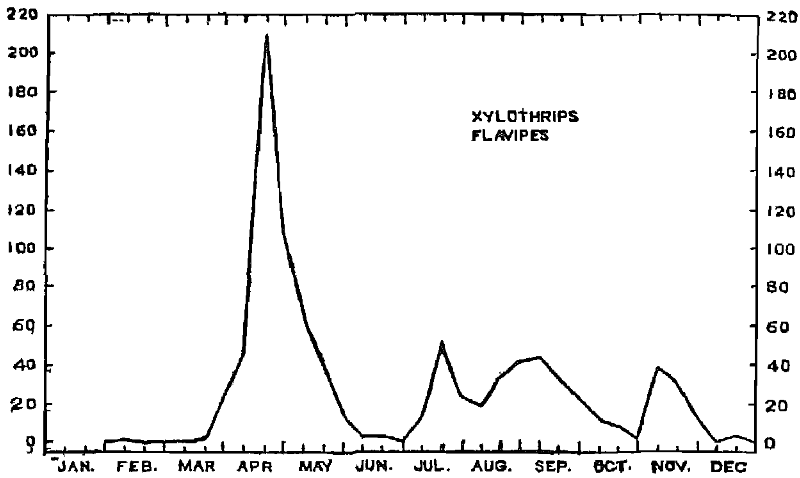


Fig. 27. Emergence-period of *Xylothrips flavipes*. Numbers of beetles emerging at intervals of one third of a month. The graph shows a sharply marked first generation from the end of March to the end of May with maximum abundance in the third week of April; a second generation during the rains from the first week of July to the third week of October; and a post-monsoon emergence in November arising from oviposition of early swarms during the rains.

Celtis australis, *Cordia myxa*, *Cynometra polyandra*, *Dalbergia latifolia*, *Dalbergia sissoo*, *Dalbergia* sp., *Dipterocarpus pilosus*, *Ficus glomerata*, *Ficus religiosa*, *Ficus rumphii*, *Garuga pinnata*, *Grevillea robusta*, *Grewia tiliaefolia*, *Kydia calycina*, *Lagerstroemia parviflora*, *Lannea grandis*, *Mallotus philippinensis*, *Mangifera indica*, *Millettia auriculata*, *Morus alba*, *Phoebe lanceolata*, *Phyllanthus emblica*, *Poinciana elata*, *Pterospermum acerifolium*, *Rhus parviflora*, *Shorea robusta*, *Sterculia alata*, *Terminalia belerica*, *Terminalia tomentosa*, *Xylia dolabriformis*, *Zizyphus rugosa*.

This widespread and common species is very variable in size and markings. It has been bred from small branchwood, woody climbers and logs of large dimensions and particularly from wood attacked while still green. It frequently bores into the wood of standing, dying or recently dead trees but does not always establish egg-tunnels. The beetle is active in full sunshine and at very high temperatures. The larva is described and figured by Gardner, (1933, *Ind. For. Rec.*, XVIII, ix, p. 17, pl. iv, fig. 57).

Beetles do not occur in the cold season. Emergence begins in April and is very well defined, reaching a peak of maximum abundance for the year in the last third of April [see text-figure 26]. It is possible for three life-cycles to be completed in a year as the

emergence-records of separate infestations show a secondary monsoon-swarming at the end of June and beginning of July and a third period of increased emergence at the beginning of October. Beetles emerge in all intermediate months except January-March, but a large proportion of each brood is composed of individuals of delayed development, many of which must remain in the wood for a year. The longest period of infestation observed is three years.

Xylophorus abnormis in *Acacia decurrens* in Ceylon.

Xylopsocus capucinus in *Anacardium occidentale, Artocarpus hirsuta, Ficus* sp., *Mallotus philippinensis, Mangifera indica, Morus alba, Nephelium litchi, Poinciana elata, Santalum album, Shorea robusta, Sindora siamensis, Swietenia mahagoni, Tectona grandis, Terminalia myriocarpa, Vitex negundo.*

This species, through widely distributed in the tropics, does not occur abundantly in India. Samples of timber attacked by it produce relatively small numbers of individuals. From material caged at Dehra Dun it emerges mainly between May and November without marked peaks of abundance and is inactive in the cold weather. The life cycle is apparently annual but may extend to two years with occasional stragglers in the third year. The larva is described and figured by Gardner, 1933, *Ind. For. Rec.*, XVIII,ix, p. 17, pl. iv, figs. 55, 56.

Xylopsocus radula in *Terminalia myriocarpa*, uncommon and usually in company with *Xylopsocus capucinus.*

Xylothrips flavipes.

Albizzia odoratissima, Anacardium occidentale, Bombax malabaricum, Butea frondosa, Canarium strictum, Dipterocarpus turbinatus, Eugenia jambolana, Ficus glomerata, Ficus religiosa, Hevea sp., *Hopea odorata, Hopea parviflora, Lannea grandis, Machilus odoratissima, Mallotus philippinensis, Mangifera indica, Myristica longifolia, Parishia insignis, Phyllanthus emblica, Poinciana elata, Pterocarpus indicus, Quercus* sp., *Shorea robusta, Terminalia bialata, Terminalia myriocarpa,Terminalia paniculata Terminalia tomentosa, Théobroma cacao, Vateria indica, Vatica lanceaefolia, Vitis vinifera.*

This widespread species [see fig. 22, beetle] is frequent in tropical and moist subtropical parts of India but is not common in the dry regions and does not ascend to high elevations. It has two generations a year in north India and under favourable conditions may complete a third. The minimum life-cycle during the monsoon period is three months; the first generation of the year beginning in April takes four months at the shortest. The emergence of the overwintering broods is sharply marked in March-May; the first generation emerges during the rains and there is a postmonsoon emergence from oviposition of early monsoon swarms. About two-thirds of the population of one infestation matures at the quicker rate and the remainder overwinters and matures in the hot weather of the second year.

BRENTHIDAE.

THE BRENTHIDAE are a family of the Rhynchophora that is characteristic of forests in the tropics and subtropics with very few representatives in temperate regions. There are about 1500 described species. What is known of their habits is based on observations made on a few Indo-Malayan species. Three biological groups can be recognised, (*a*) the larvae bore tunnels in the wood of dead trees from eggs laid by the female on the bark or sapwood, i.e., true wood-borers, (*b*) the larvae bore tunnels in the wood from eggs laid by the female inside the tunnels of other wood-borers, i.e., agressors, (*c*) the beetles are mymecophilous and the larval habits are unknown.

The adult beetles occur gregariously between the loose bark and wood of trees that have been attacked by bark and sapwood-boring larvae, (mainly Cerambycidae); they often hibernate under dead bark in company with histerids, staphylinids and Clavicornia, but may be found in most months of the year in such places or on logs and dead trees.

(*a*) Wood-borers: The eggs are deposited singly on the surface of the sapwood under the shelter of the wood-dust and fibres in the excavations of surface-borers. In many genera the female bores a hole in the wood with the mandibles for the reception of the egg. The larva [see fig. 28] constructs its own gallery more less radially into the wood, and feeds like the Lymexylonidae and Platypodidae on sap or saprophytic fungi growing in the gallery. Pupation usually occurs in a cell enlarged along the axis of tunnel, and emergence takes place via the external aperture of the tunnel on the sapwood-surface, i.e., the site of oviposition, e.g., *Cerobates, Jonthocerus*. The life-cycle in this group is on an annual basis with the main emergence-period in the pre-monsoon hot weather but is prolonged for several months.

(*b*) Agressors: This simple type of life-history may be modified by the utilisation of the internal tunnels of other wood-borers for oviposition with the construction of larval galleries at right angles to the wall of the tunnels, as e.g., the case of *Microtrachelizus beneficus* in the tunnels of *Hoplocerambyx spinicornis* (Cerambycidae). This is a case of simple synoecy or shelter-association. A further modification occurs when the utilisation of the gallery of another wood-borer involves the ejection of the rightful occupant, e.g., in the case of many species of *Cyphagogus* and the Platypodidae. Thus in the adult stage they are competitors with other wood-borers for breeding-sites, laying their eggs in the galleries of shothole-borers of the families Platypodidae and Scolytidae. The *Cyphagogus* female may not wait until the galleries of their shothole-boring hosts are vacated, but may kill or eject the inhabitants of those galleries in which tenants are

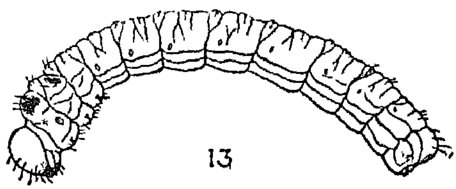


Fig. 28. Larva of *Trachelizus bisulcatus*, natural size 12 mm.; a primary wood-boring species of group (a) Brenthidae.

encountered. The mandibles of *Cyphagogus* are suitable for successful attack on the posterior portion of a platypodid beetle, whose chief means of defending the brood-gallery is by interposing its body as a living plug.

Kleine (1923) terms this type of life-history "Brutparasitismus der ziemlich rucksichtslos und robust ausgefuhrt wird". V. Lengerken (1939) calls the beetles "rauberische Raumparasiten". Escherisch (1923) uses the term "Wohnungsparasitismus" for a similar state in *Crypturgus* (Scolytidae). It is however by no means parasitism but is rather a form of competitive commensalism that has reached a degree at which it becomes stark murderous agression.

Since the life-cycle of brenthids progresses concurrently with those of primary wood-borers, the family should be ranked among the borers of freshly felled or fallen timber, rather than among those groups, that establish themselves only after the timber has lost a high proportion of its moisture and has begun to decay.

(c) Myrmecophiles: The myrmecophilous group of Brenthidae includes two types: symphilines and robbers. The former live in association with ants nesting in the soil as well as in plants, and are characterised by the possession of exudatory organs. The latter are usually without excretory pores, but exhibit other anatomical modifications. Nothing is known of their larval habits.

The larva of the wood-boring brenthids is gently curved, cylindrical, usually rather abruptly expanded at the metathorax and tapering thence to the small head, and also more or less expanded at the posterior end. Legs are absent in one group and small, 2-segmented in the rest [fig. 28]. For descriptions and figures see Gardner, 1935. What is the food of the wood-boring brenthid larva is still undiscovered; from the short length of the tunnel, the absence of wood-dust in it and the staining of the walls it is very probable that sap or ambrosia fungus is the chief food-substance.

LITERATURE ON BRENTHIDAE:

Beeson, 1925, *Ind. For. Rec*, Ent., XI, iv, pp. 171-188, pls. iii, Notes on the biology of the Brenthidae.

Gardner J.C.M. 1925, *Ind. For. Rec.*, Ent. XI, iv, pp. 189-194, pl. iv, Larvae of Cerobates tristriatus and C. sexsulcatus.

— 1935, *lit. cit.*, Ent., 1, No. 7, pp. 139-148, figs. 1-31, Immature stages of Indian Coleoptera (18).
Kleine R., 1925, *Ind. For. Rec.*, Ent., xi, iv, pp. 123-170, pls. i, ii.
— 1926, *Catalogue of Indian Insects*, 11, Brenthidae, pp 50.
— 1933, *Ind. For Rec*, xviii, ii, Entomological investigations of the spike disease of sandal (5). Brenthidae and Lycidae.

Allaeometrus breviceps occurs from India to Australia. The larval tunnel in *Shorea robusta* runs radially and at right angles to the surface of the sapwood.

Allaeometrus deformis also in *Shorea robusta*.

Amphicordus improportionalis in *Pentacme suavis*.

Aneorhachis astrictus in *Erythrina indica*.

Anepsiotes commendabilis in *Eugenia jambolana*. Emergence in May, June. The larva (16 mm. long) is described by Gardner, 1935, *Ind. For. Rec.*, Ent., 1, No. 7, p. 146, figs. 30,31.

Anisognathus distortus in *Garcinia* sp.

Araiorrhinus beesoni in *Tectona grandis*.

Arrhenodes dispar in *Coffea liberica*.

Arrhenodes flavolineatus in *Ochroma lagopus*.

Baryrrhynchus dehiscens in *Balanocarpus heimii*, *Shorea* sp. May, June.

Baryrrhynchus miles, a widely distributed oriental species, in *Alphonsea ventricosa*, *Diospyros lanceaefolia*, *Elaeocarpus varunna*, *Macaranga denticulata*, *Michelia champaca*, *Terminalia belerica*, *Zanthoxylum budrunga*. Emergence occurs in April–July or August; the generation is annual. [see fig. 4, No. 43 for beetle, natural size].

Caenorychodes planicollis in *Albizzia procera*, *Albizzia* sp., *Alphonsea ventricosa*, *Bombax malabaricum*, *Boswellia serrata*, *Diospyros lanceaefolia*, *Ficus religiosa*, *F. rumphii*, *Hymenodictyon excelsum*, *Poinciana elata*, *Tetrameles nudiflora*. Occurs from Ceylon to Formosa. Emergence in April–August.

Calodromus mellyi occurs in the galleries of shothole-borers in *Vatica lanceaefolia* in Assam, but is a widely spread oriental species. In habits it is predaceous like species of *Cyphagogus*.

Carcinopisthius maculatus in *Artocarpus lakoocha*, *Dipterocarpus pilosus*. May.

Carcinopisthius oberthuri, a borer of *Dipterocarpus pilosus*, *Sapium eugeniaefolium*, *Sterculia colorata*. The larva, 5 mm., is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I, No. 7, p. 145. The larval tunnels occur in clusters connected with the brood-tunnels of large species of Platypodidae. Very coarse particles of wood-dust are produced in their excavation; in the later stages they are kept clear of dust to allow a food-fungus to grow.

Cerobates adustus in *Ficus* sp., *Bombax malabaricum*.

Cerobates aemulus in *Shorea leprosula*.

Cerobates aequalis in *Bombax insigne*, *Sterculia colorata*.

Cerobates birmanicus in *Ficus rumphii, F. tjakela, Garuga pinnata.* Emergence in May, June.

Cerobates concisus in *Garuga pinnata, Poinciana elata.* Emergence in May.

Cerobates fossulatus in *Artocarpus lakoocha.*

Cerobates sexsulcatus in *Albizzia lucida, Albizzia procera, Artocarpus integrifolia, Artocarpus kunstleri, Bombax malabaricum, Butea frondosa, Dysoxylum binectariferum, Santalum album, Shorea scleroxylon.* Widely distributed in the Oriental Region. Its life history is similar to that of *Cerobates tristriatus*, an annual generation with emergence mainly in May, June but prolonged irregularly. The larva is described by Gardner, 1924, *Ind. For. Rec.*, XI, iv, p. 193.

Cerobates sumatranus in *Artocarpus integrifolia, Dysoxylum binectariferum.* Emergence occurs in April–August and may be prolonged to October.

Cerobates tristriatus in *Artocarpus integrifolia, Bombax malabaricum, Butea frondosa, Moringa pterygosperma.* Widely distributed in the Oriental and Australian Regions.

Life-history: The beetles lay eggs singly on the surface of the sapwood of trees with partially decayed bark; the larva bores a radial gallery into the soft wood; in timbers with a marked heartwood the gallery turns and runs on the surface of the heartwood. In its early stages the gallery is very slightly tapered, increasing in diameter from the fine needle-hole on the surface of the wood towards the centre of the log. Its final length does not exceed three inches; its course in the horizontal plane is straight or slightly curved; it contains fine wood-dust at the outer end and is empty in the newer portions. In its later stages the gallery is widened uniformly throughout with the growth in size of the larva except at the extreme outer end, which remains as a fine needle-hole. The diameter is sufficiently great to permit the larva to turn freely in the gallery. The products of excavation are apparently ejected at intervals, although near the time of pupation it may contain a quantity of moist excrement and wood-dust, which readily becomes discoloured and permeated with mycelium. The galleries occur in close groups more or less intermingled but not communicating or branching. Sometimes they intersect *Xyleborus* galleries so that *Cerobates* larvae may be found in *Xyleborus* galleries and the scolytids may wander into the brenthid galleries. In the development of its gallery *Cerobates* resembles the lymexylonid *Hylocoetus* and apparently its food is similarly sap and moulds.

The emergence-period is prolonged but beetles appear in greatest abundance in April and October, November.

A description of the larva (length 8 mm. x 1 mm.) is given by Gardner, 1924, *Ind. For. Rec.*, Ent., XI, iv, pp. 189–192, pl. 4, figs. 1–8.

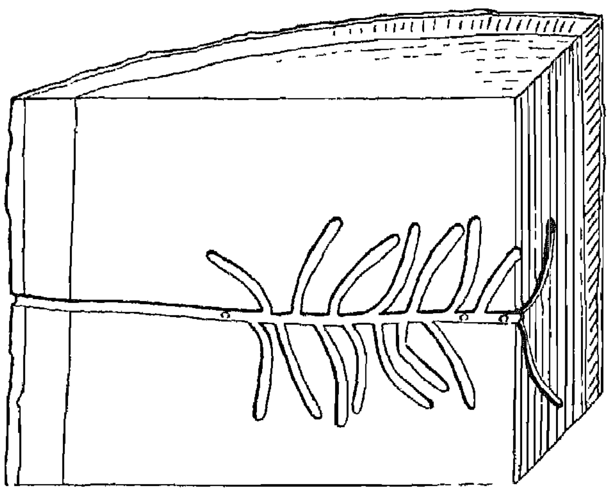


Fig. 29. System of tunnels of *Cyphagogus corporaali.* The horizontal tunnel running from the bark into the wood was made by *Platypus solidus*; the tunnels of the larvae of *C. corporaali* curve outwards above and below the *Platypus* tunnel. About natural size.

In the genus **Cyphagogus** the beetles are agressive competitors for sites for oviposition and larval food-material in dead trees; they utilise the tunnels of other wood-borers especially of the Platypodidae which are ejected or killed.

Cyphagogus brownei in *Shorea hypochra.*

Cyphagogus buccatus is a brood-parasite of shothole-borers of *Albizzia odoratissima, Cryptocarya wightiana, Isonandra polyantha, Mimusops littoralis, Myristica andamanica, M. longifolia, Shorea robusta, Tectona grandis.* Widely distributed in the Oriental Region.

The female makes use of the tunnels of a platypodid beetle for oviposition and deposits her eggs at a depth of 1/2 to 1 inch from the surface of the sapwood. The larval tunnels extend on all sides from the wall of the platypodid gallery for variable distances 1/8th to 1/2 an inch, before the pupal cell is reached; they are filled with fine wood-dust more closely packed at the mouth of the pupal cell. While the prepupal portion of the tunnel may run horizontally or curve the pupal chamber appears always to lie vertically in the trend of the fibres. Emergence occurs in April–July, mainly May. The larva is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I, No. 7, p. 143.

Cyphagogus confertulus in *Mesua ferrea, Pentacme suavis.*

Cyphagogus confidens in *Shorea eximia, S. parvifolia, S. pauciflora, S. platycarpa.*

Cyphagogus corporaali in *Bauhinia purpurea*, *Bombax malabaricum*, *Butea frondosa*, *Pentacme suavis*, *Tectona grandis*.

The galleries of *Cyphagogus corporaali* [fig. 29] originate at short intervals from the wall of the main horizontal gallery of *Platypus solidus*, from which they curve outwards and vertically upwards or downwards for a distance of up to an inch. The terminal portion forms a pupal chamber in which the insects occur with their heads directed towards the *Platypus* gallery, through which the successful individuals make their escape. The prepupal portion of the gallery is packed with fine normally-coloured wood-dust. The diameter of the pupal chamber is slightly greater than that of the *Platypus* gallery, but the holes bitten by the emerging beetles in the walls of the latter are slightly smaller and vary with the size of the individual. The chief emergence of the beetles of *C. corporaali* is in February–May.

Cyphagogus dissociabilis and **C. eggersi** in *Shorea hypochra*.

Cyphagogus eichhorni in *Bombax malabaricum*.

Cyphagogus gemellus, *Ficus* sp.

Cyphagogus gladiator in *Mallotus albus*, *Mesua ferrea*.

Cyphagogus incisus in *Calophyllum spectabile*, *Terminalia myriocarpa*.

Cyphagogus longisetosus in *Shorea bracteolata*, *S. hypochra*, *S. leprosula*.

Cyphagogus obconiceps in *Chickrassia tabularis*, *Ficus* sp., *Shorea* sp., *Terminalia myriocarpa*, *Vatica lanceaefolia*.

The larva is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I, No. 7, p. 143.

Cyphagogus planifrons in *Mesua ferrea*, *Myristica longifolia*, *Terminalia myriocarpa*, *Vatica lanceaefolia*.

Cyphagogus raptor in *Shorea parvifolia*, in tunnels of *Platypus curtus*.

Cyphagogus silvanus in *Pentacme suavis*.

Cyphagogus simulator in *Isonandra polyantha*, *Vatica lanceaefolia*.

Cyphagogus tabacicola in *Heritiera fomes*, *Melanorrhoea usitata*, *Vatica lanceaefolia*.

Cyphagogus westwoodi in *Canarium* sp., *Cryptocarya wightiana*, *Ficus* sp., *Heritiera fomes*, *Hopea odorata*, *Intsia bakeri*, *Lannea grandis*, *Myristica longifolia*, *Poinciana elata*, *Protium serratum*, *Semecarpus gardneri*, *Shorea* sp., *Terminalia belerica*, *Vatica lanceaefolia*, *Warmia triquetra*.

Widely distributed in the Oriental Region. [see fig. 4, No. 42 for beetle natural size]. The brenthid galleries are grouped in clusters or whorls originating from the horizontal, radial tunnels of *Crossotarsus saundersi* and of large species of *Xyleborus*, e.g., *X. foersteri* (Scolytidae) other Platypodidae. The gallery of the *Crossotarsus* is in places slightly enlarged, and irregularly pitted with niches, that are the sites of oviposition. From these points

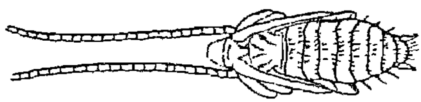


Fig. 30. Male pupa of *Jonthoceras carinensis*, natural size 10 mm.

the *Cyphagogus* larval work extends in short curved tunnels of increasing diameter, and terminates in pupal cells closed by plugs of dust and fine fibres. No one of the galleries exceeds five times the length of the beetle. Galleries from which the beetles have successfully emerged are, of necessity, enlarged towards their proximal end, to obtain access to the egg-tunnel by which escape from the tree takes place. Emergence of beetles is extended without well marked premonsoon swarming.

Diurus sphacelatus in *Diospyros glandulosa.* March-May.

Ectocemus badeni in *Ceiba pentandra.*

Ectocemus cinnamomi in *Cinnamomum* sp., *Mangifera zeylanica, Sloetia sideroxylon.* The larva, 18 mm., is described by Gardner, 1939, *Ind. For. Rec.*, Ent., I, No. 7, p. 147.

Eupsalis truncata in *Artocarpus integrifolia, Bombax malabaricum, Eugenia* sp., *Euphorbia* sp., *Ficus tsiela, Moringa pterygosperma.* Emergence in May–July and November. The larva, 13 mm., is described by Gardner, 1935, *Ind. For. Rec.*, Ent. I, No. 7, p. 147, figs. 28,29.

Eupsalis vulsellata in *Acacia* sp., *Vitex hildebrandtii.*

Eusebus adelphus in *Butea frondosa.*

Hemiorychodes compactus in *Calophyllum tomentosum, Hopea parviflora.* May–July.

Higonius cilo in *Amoora wallichii, Castanopsis tribuloides, Mallotus roxburghianus, Millettia auriculata.* April–August. The larva, 5 mm., is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I, No. 7, p. 145.

Higonius crux in *Diospyros pyrrhocarpa, Shorea robusta, Sterculia alata, Tectona grandis, Terminalia myriocarpa, Tetrameles nudiflora.* January–May. Probably a brood-parasite of Platypodidae.

Holotrachelus comparabilis in *Dryobalanops aromatica.*

Hoplopisthius trichimerus in *Dalbergia assamica, Pterocymbium* sp.,

Hormocerus reticulatus in *Artocarpus integrifolia, Bombax malabaricum, Castanopsis tribuloides, Ficus infectoria, Hymenodictyon excelsum, Tetrameles nudiflora.* Emergence in April–July; hibernating beetles occur under loose bark.

Hypomiolispa incerta in *Anthocephalus cadamba.* May.

Jonthocerus carinensis in *Albizzia procera, Erythrina arborescens, Neonauclea griffithii.* April, May. The larva, 6 mm., is described by Gardner, 1935, *Ind. For. Rec.*, I, No. 7, pp. 143, 144, figs. 8,9 and pupa fig. 10. [see fig. 30].

Jonthocerus crematus in *Artocarpus integrifolia, Diospyros pyrrhocarpa.* The emergence-period is prolonged; beetles emerged from *Artocarpus integrifolia* (large rootstock) at the following monthly rates:—

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
First year	.	.	.	.	3	20	35	40	9	4	1	1
Second year	0	1	4	6	1	1	.	.	.	.	.	

The larval tunnels are more or less horizontal (to the axis of the standing tree) and radial as far as the heartwood where they turn and run concentrically with the zones of growth, reaching a maximum length of about 5 inches. They are subsequently cleared of wood-dust and the bore of the tunnel is made cylindrical throughout and the walls become stained black. The beetle emerges from the external end of the tunnel on the surface of the sapwood.

Mesoderes aberrans in *Bombax malabaricum, Butea frondosa.*

Mesoderes sexnotatus in *Terminalia bialata.*

Metatrachelizus abjectus in *Shorea* sp.

Microtrachelizus accomodatus in *Shorea assamica, Vateria indica.*

Microtrachelizus apertus in *Bombax malabaricum, Dalbergia assamica, Ehretia acuminata, Mesua ferrea, Ostodes paniculata, Sterculia villosa.*

Microtrachelizus attritus in *Erythrina indica, Miliusa velutina.*

Microtrachelizus beneficus in *Litsaea citrata, Shorea assamica,* and *S. robusta.*

Life-history: This species makes use of the prepupal tunnels of *Hoplocerambyx spinicornis* as sites for oviposition. The parents enter the bark of the bored log by means of ejection-holes, etc., and while the mature larvae of *Hoplocerambyx spinicornis* are hibernating they penetrate the tunnels leading from the sapwood to the pupal chamber in the heartwood. The prepupal tunnels are usually filled with coarse fibres derived from the heartwood, but these are not packed tightly enough to offer obstruction to the brenthid. Eggs are laid singly but abundantly on the wall of the tunnel [vide fig. 31 which shows the distribution of oviposition sites on the wall of the prepupal tunnel]. The larvae hatching out excavate tunnels, one to two inches long, that curve outwards in a whorl from the *Hoplocerambyx* tunnel. Presumably their food is sap and saprophytic fungi, as the larvae evidently move freely to and fro and the abandoned tunnels are found to contain mainly mildewed excrement with very little wood-dust. Pupation takes place in a slightly enlarged chamber at the base

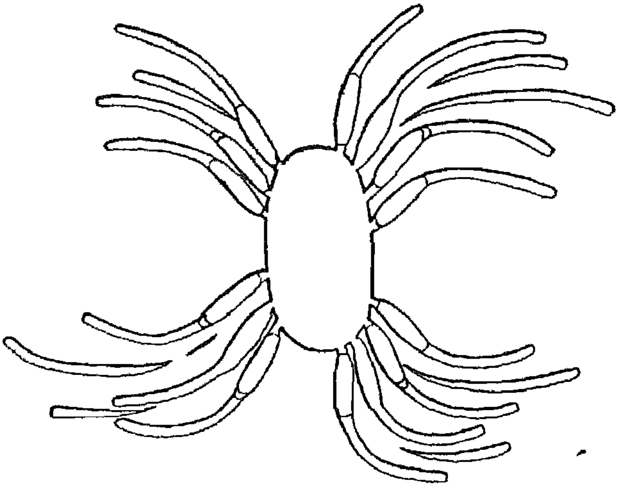


Fig. 31. System of tunnels of *Microtrachelizus beneficus.* The central oval is a cross-section of the prepupal tunnel of *Hoplocerambyx spinicornis;* larval tunnels *M. beneficus* form a whorl from its circumference; the pupal chamber is enlarged at the basal or inner end of the larval tunnel. About natural size.

of the larval gallery; the pupal chamber is plugged at both ends before the larva pupates. The beetle emerges by enlarging the orifice of the larval gallery and escapes into the *Hoplocerambyx* tunnel.

The emergence-period of *Michrotrachelizus beneficus* is prolonged for a year with two marked swarms occurring from mid-November to the end of December, and mid April to mid June,—the latter being less abundant. It is possible that the two swarm-periods represent two generations of *Microtrachelizus beneficus.* If that is so, the May brood must normally use another host than *Hoplocerambyx spinicornis* (whose prepupal tunnels are available only in the autumn and cold weather), whenever the timber dries up fast enough to make it unsuitable for re-attack.

Microtrachelizus contiguus in *Calesium grande, Terminalia bialata.*

Microtrachelizus siamensis in *Elateriospermum* sp.

Microtrachelizus tabaci in *Shorea bracteolata.*

Opisthenoplus cavus in *Anthocephalus cadamba, Artocarpus integrifolia, Buchanania latifolia, Calesium grande, Kydia calycina, Lannea grandis, Mangifera indica, Semecarpus anacardium, Shorea robusta, Terminalia chebula, T. tomentosa.* Emergence occurs in May-July. The larva, 15 mm, is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I, No. 7, p. 148, figs. 17-25.

Opisthenoplus fascinatus in *Butea frondosa*, *Terminalia belerica*, *T. chebula*.

Opisthenoplus madens in *Artocarpus lakoocha*.

Opisthenoxys bistriatus in *Quercus spicata*. Emergence in February, March. The larva is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I, No. 7, p. 143.

Opisthenoxys ochraceus in *Dipterocarpus cornutus*, *D. pilosus*, *Shorea hypochra*. August.

Parorychodes cereus in *Alphonsea ventricosa*.

Pittodes mediocris has been bred from unidentified wood in Bengal in May-September. The larva, 6 mm., is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I, No. 7, p. 142, figs. 1-5.

Prophthalmus bourgeoisi in *Artocarpus integrifolia*.

Prophthalmus delesserti in *Poinciana elata*.

Prophthalmus heikertingeri in *Casearia glomerata*. The larva, 20 mm., is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I No. 7, p. 147, fig. 27.

Prophthalmus tridentatus in *Pterospermum acerifolium*.

Pseudocyphagogus squamifer in *Dipterocarpus pilosus*, *Shorea assamica*, *Terminalia bialata*. Emergence occurs in March-June, mainly in May. The larval galleries are in the sap-wood in the form of short radial tunnels connected with vertical and horizontal branches of variable diameter.

Pseudopisthenoxys insculptus in *Quercus serrata*.

Pseudorychodes crassus in *Macaranga denticulata*, *Symplocos theaefolia*. March-May.

Pseudorychodes lineolatus in *Shorea hypochra*.

Schizotrachelus cameratus in *Dyera costulata*.

Suborychodes intermedius in *Shorea assamica*, *S. laevis*, *S. robusta*, *S. talura*. Emergence in April-June, mainly early May.

Trachelizus bisulcatus in *Albizzia* sp., *Anogeissus latifolia*, *Anthocephalus cadamba*, *Bombax malabaricum*, *Buchanania latifolia*, *Butea frondosa*, *Erythrina indica*, *Euphorbia royleana*, *Ficus asperrima*, *Ficus bengalensis*, *F. glomerata*, *F. religiosa*, *F. rumphii*, *Hodgsonia heteroclita*, *Kydia calycina*, *Opuntia* sp., *Poinciana elata*, *Sterculia colorata*, *Tectona grandis*, *Tetrameles nudiflora*.

Although this species is common and widespread in the Oriental and Australasian Regions and occurs upto 5,000 feet in the hills, little is known of its habits beyond that it is a wood-borer making long cylindrical tunnels more or less horizontal (to the axis of the standing tree) and radial or concentric with the zones of growth; the tunnels contain loosely packed coarse wood-dust which is subsequently cleared out and the walls of the tunnels discolour or blacken indicating growth of mould or food-fungus. The life-cycle is annual, beginning emergence in April and appearing irregularly until October. Beetles shelter for the cold season

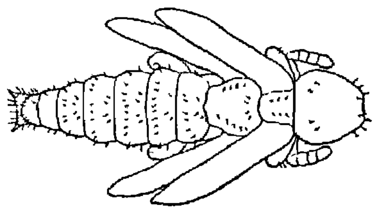


Fig. 32. Pupa of *Trachelizus bisulcatus.* Natural size 8 mm.

under loose bark. The larva [fig. 28] is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I, No. 7, pp. 144, 145, figs. 11-15, and pupa fig. 16 [see fig. 4, No. 41 for beetle, natural size and fig. 32 for pupa, enlarged].

Trachelizus politus in *Anthocephalus cadamba.*

BRUCHIDAE.

PULSE Beetles, Bean and Pea Weevils, or simply Seed Weevils are some of the names by which BRUCHIDAE are known in commerce, and it is as pests of harvested and stored food-grains and seeds, particularly of legumes, that they have received most study. Many species are injurious to seeds of forest trees.

The life-history is very similar in all genera. The shining oval eggs are normally laid on the outer skin of the pod or fruit to which they are attached firmly by an adhesive fluid. The larva hatches in a few days. The larva [fig. 33] on hatching bores from the egg directly through the rind of the fruit or pod inwards to the seed. It is helped in this effort by means of a curved H-shaped chitinous plate on the back of the first thoracic segment which is used as a lever or point of purchase to incline and steady the head while biting. When it has entered the seed it moults and the second instar has no chitinous plate on the thorax ; it is also devoid of legs. The larva feeds on the interior of the seed hollowing it out, and passing on to the next seed in a pod in some cases, according to the species of bruchid or plant. Before pupating it prepares a cell and cuts a ring in the skin of the seed. The beetle [fig. 33] remains for a variable time maturing and eventually cuts out a circular disc and escapes. The whole life-cycle requires 18 days to seven weeks, varying with the kind of food as well as the climate. In stored seeds crowded in a receptacle the beetles invariably make their way upwards to the surface and pair in freedom ; they may live for considerable periods and overwinter.

The most favourable conditions for existence are found in the accumulated food-supply provided by seeds kept in storage in bags

or vessels inside which the weevils multiply rapidly from a very small initial infestation ; eggs are laid directly on the surface of the ripe seed in the upper layers.

For control of Bruchidae see Part Two, Bruchidae, Seed Weevils.

LITERATURE ON BRUCHIDAE :

Ghosh C. C., 1937, *Ind. Journ. Agr. Sci.*, VII, pp 395–412, pls. XXXII, XXXIII, The pulse beetles (Bruchidae) of Burma.

Kunhi Kannan K., 1919, *Mysore Dept. Agr.*, Ent. Ser., Bull. No. 6, pp. 31, figs. 18, Pulse beetles, Store forms.

— 1919, *Mysore Agric Calendar*, pp. 13,16.17, figs. 2.

— 1920, *Proc. 3rd ent meeting, Pusa*, pp. 858, 859, The function of the chitinous plate in B. chinensis.

Bruchus bilineatopygus in seeds of *Albizzia procera.*

Bruchus chinensis is a cosmopolitan species and a pest of all pulse crops and stored leguminous seeds. [see fig. 33 for larva and beetle]. The life-cycle varies from 3 to 7 weeks.

LITERATURE :

Ghosh C. C., 1937, *Ind. Journ Agr. Sci.*, VII, pp. 396,399, figs. 1–3.

Kunhi Kannan K., 1919, *Mysore Dept. Agr.*, Ent. Ser., Bull. No. 6, pp. 31, figs. 18.

Bruchus maculatithorax in seeds of *Dalbergia paniculata.* Beetle in February–May.

Bruchus maculipyga in seeds of *Acacia pennata.*

Bruchus nalandus in seeds of *Acacia leucophloea, Desmodium pulchellum.* Emergence in March, April.

Bruchus pisorum in seeds of *Albizzia lebbek, Cassia fistula* and *Dalbergia sisso.*

Bruchus saundersi in seeds of *Albizzia lebbek.*

Bruchus schroderi importatus in seeds of *Albizzia amara* and *A. procera.*

Bruchus sparsemaculatus in seeds of *Albizzia lebbek.*

Bruchus uberatus in seeds of *Abrus precatorius, Acacia modesta, Albizzia amara, Dalbergia paniculata, Prosopis juliflora.* Beetles occur from December to June.

Bruchus urbanus in seeds of *Albizzia julibrissin.*

Caryoborus see **Pachymerus.**

Caryopemon cruciger in seeds of *Abrus precatorius.*

Caryopemon hieroglyphicus feeds on the glands of young leaves of *Acacia intsia.*

Pachymerus gonagra is a large bruchid, 5 to 6 mm. long, and probably the most injurious of the forest tree seed weevils. It is a pest of seeds of *Acacia arabica, A. farnesiana, A. pennata, Albizzia lebbek, Bauhinia malabarica, B. racemosa, Cassia fistula, C. montanus,* and *Tamarindus indica.* This widespread species breeds readily in stored seeds for many successive generations ; the longest continuous infestation recorded in the Dehra Dun insectary lasted for 9 years in seeds of *Acacia arabica.* Pupation occurs in an ovoid cocoon of tough silk. Beetles mature and

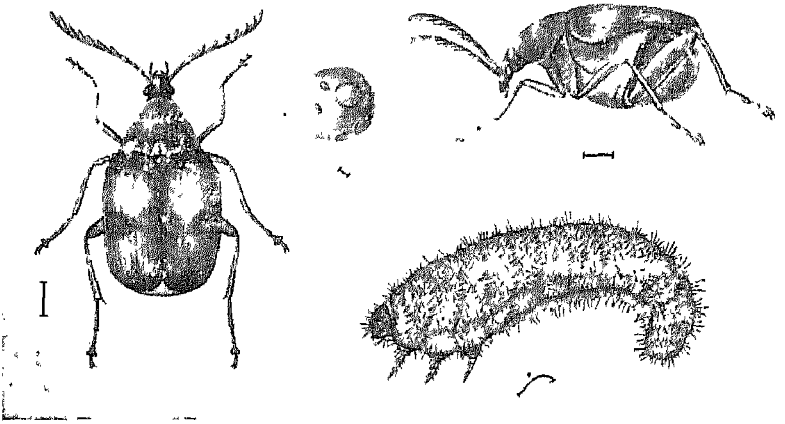


Fig. 33. Beetle and larva of *Bruchus chinensis ;* three eggs are laid on the pea ; the natural size of all objects is indicated by the adjacent hair-line.

leave the seeds in every month of the year in varying abundance ; the average length of a generation has not been determined as broods of all stages of several generations overlap ; it is presumed that there are at least six per annum. Control measures are prescribed in Part Two, section Bruchidae, Seed Weevils.

Pachymerus languidus in seeds of *Cassia auriculata.* Beetles occur from May to October.

Spermophagus abdominalis in seeds of *Ipomoea hederacea.* Beetles occur throughout the year in south India.

BUPRESTIDAE

BUPRESTIDAE are somewhat elongate depressed beetles with the head retracted into the prothorax as far as the eyes, the pronotum margined at the sides and fitting closely to the elytra which are often truncate and toothed at the apices [fig. 34]. The size varies from about 1/4th of an inch to 3 inches. The cuticle is hard and often brilliantly coloured with metallic lustre and pure tints of considerable beauty, rivalling anything in the Class Insecta. On this account they are equally prized by insect collectors as by primitive peoples, who use the entire beetle or the elytra for personal adornments (necklaces, embroidered cloth, hair-ornaments, charms, etc.). Nearly 12,000 species have been described. The collections made in the Indian area in recent years have been studied by Bourgoin, Gebhardt, Obenberger and Thery.

The larva or "flatheaded borer" is a long, soft, whitish, legless

grub with a small head withdrawn into the prothorax. This segment is widened into a large, flat, oval or nearly circular disc, its surface soft and velvety or roughened, usually with two convergent lines above and one below [fig. 34]. The hind part of the body is slender and flexible with the 2 thoracic and 9 abdominal segments distinct; the cross-section is oval or subcylindrical but in some forms flattened almost to a tape-like thinness. In one type of larva, (*Agrilus* and allies) the end of the abdomen bears a pair of spine-like processes, and the prothorax is very little wider than the abdominal segments. Larvae of some Indian Buprestidae have been described by Gardner.

Ecology: The beetles of some genera (*Sternocera*) feed on leaves and of other genera (*Psiloptera*) gnaw the bark of living twigs. Eggs are laid singly or in a small clusters of 3-6 on the bark of dead or dying trees; healthy trunks or branches are not normally attacked by Buprestidae. Kalshoven (1929) records the killing off of *Actinophora fragrans* in Java by the attack of *Agrilus kalshoveni* which makes zigzag tunnels in the cambium of large trees. No primary attack of this nature has been recorded in India. The outbreak in Java followed severe drought; slightly attacked trees recovered. Beetles of *Melanophila* are attracted to burning and burnt forests. The egg of *Sternocera* is large and stoutly ovoid and has two strong respiratory spines originating from the embryo and piercing the egg-membrances. Oviposition occurs in the soil in July and the egg remains unhatched till the following April.

The larvae may be considered as (a) bark- and sapwood-borers and, (b) dry-wood-borers, (c) twig-girdlers, (d) leaf-miners. No detailed study of the life-history has been made. In the first three types, the larva on hatching from the egg bores between the bark and sapwood an irregular rambling gallery, which is closely packed with wood-dust, the packing often visible as concave lines in the wake of the larva's progress. In a crowded attack the galleries of various larvae cross and interlace and the course of each is not traceable throughout. The cross-section of the gallery of *Agrilus* larvae is correspondingly deeper than that of the thin-bodied larvae and they are usually not crowded or intersected. The dry-wood-boring larvae leave the surface of the sapwood and penetrate the wood-working through it irregularly until eventually the whole may be reduced to a mass of fine powdery wood-dust with plates or paper-thin flakes of wood left here and there (e.g., *Buprestis geometrica*, *Chrysochroa gratiosa*). The mature larva pupates near the surface of the wood in a short vertical pupal chamber. The beetle of the "flatheaded" larvae (*Buprestis, Chrysobothris*) emerges by way of the entrance tunnel to the pupal chamber; the beetle of the *Agrilus* group emerges by a secondary tunnel excavated from the base of the pupal chamber to the bark, i.e., the empty pupal chamber has two openings. The

emergence-hole of the beetle in the bark is oval or rounded triangular in cross-section and thereby distinguishable from the circular hole of Bostrychidae and the more rectangular hole of Cerambycidae. The life-cycle is normally annual but may be prolonged for two years or more in the dry wood boring species. Beetles emerge in the dry hot weather April, May, and frequent flowers or foliage and are very active in sunshine.

The twig-girdling species make very thin galleries running spirally between the bark and sapwood. The twig dies back to the point of complete girdling and in the case of *Acacia* spp. produces a nodule of gum.

The effect of the leaf-mining species *(Trachys)* is visible in the form of blisters and dry tissue over the larval mines, and results in leaf-shedding.

LITERATURE ON BUPRESTIDAE :

Beeson, 1919, *Ind. For.*, pp. 139–142, The food-plants of Indian forest insects II.

Gardner J. C. M., 1929, *Ind. For. Rec.*, Ent., XIV, iv, pp. 111-121, pl. iii, iv, Immature stages of Indian Coleoptera (6)—1930, *tit. cit.*, XIV, xiii, p. 281, figs., *ibid* (7).

Kalshoven, L. G. E., 1929, *Tectona*, XXII, Jan., pp. 22, figs. 11, Massaal afsterven van walikoekoen–boomen door den zigzag boorder.

— *tit. cit.*, April, 9 pp., fig. 1. De reactie der walikoekoen–boomen op de aantasting door dem zigzagboorder

Stebbing E. P., 1914, *Ind. For. Ins.* (coloured illustrations of buprestid beetles).

Thery A., 1928, *Ind. For. Rec.*, Ent., XIII, pp. 269, 270. A new Agrilus from India.

The following species of Buprestidae are, unless otherwise described, borers between the bark and wood or in the sapwood of the trees recorded. The months following the names of the food-plant indicate the emergence and flight-period of the beetle. The generation is normally annual and beetles are most active in the early hot weather.

The widespread genus **Acmaeodera** includes small beetles, 6-10 mm. long, with a yellow pattern on a dark ground.

Acmaeodera aurifera bores small branches and roots of *Acacia arabica* and *A. catechu.* Emergence occurs in July, August; the annual life-cycle may be prolonged for 2 years.

Acmaeodera beesoni, a borer of *Butea frondosa.* May.

Acmaeodera gardneri, *Shorea robusta.* May.

Acmaeodera interrupta in *Ficus religiosa* and dry crowns of *Shorea robusta.* May, June.

Acmaeodera kerremansi, in *Dalbergia sissoo*, *Mallotus philippinensis*, *Terminalia tomentosa.* The variety **fasciatipennis** in *Bauhinia purpurea*, *Butea frondosa*, *Mallotus philippinensis*, and *Ougeinia dalbergioides.* Beetle, black, with irregular orange bands and spots, 6 mm. [fig. 4, No. 40]. Larva, a "flatheaded borer", 11 mm. Bores the surface of the sapwood of logs and branchwood in flat, irregular tunnels packed with dust

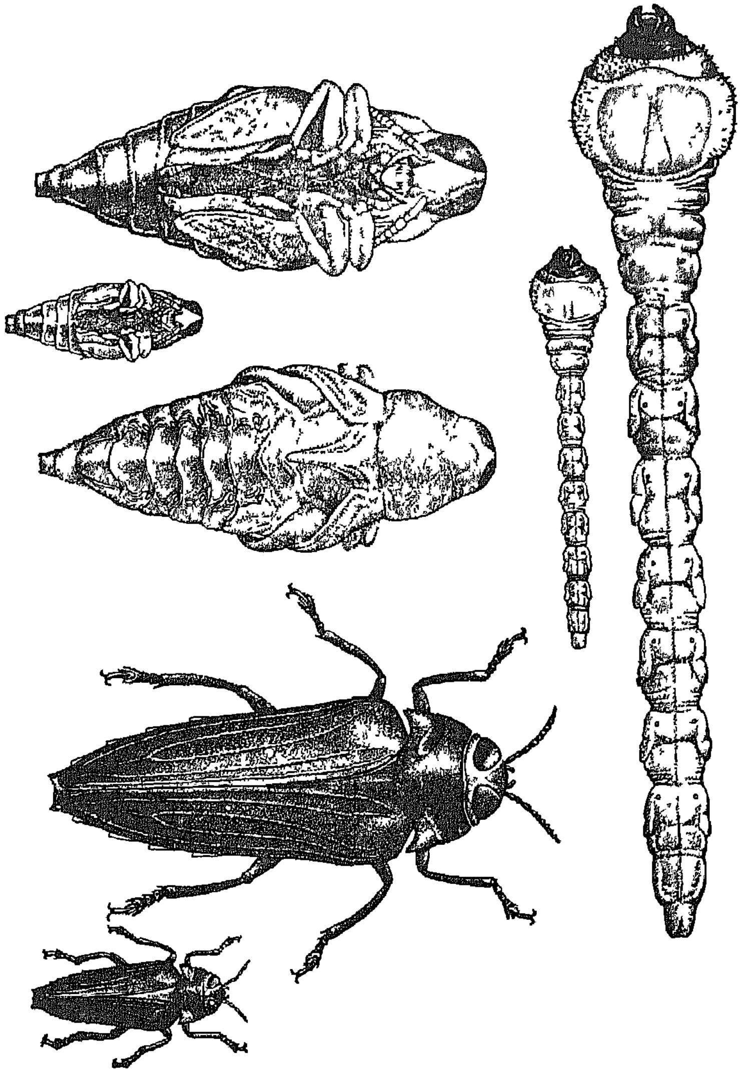


Fig. 34. Larva, pupa and beetle of *Belionota prasina*, a polyphagous wood-borer : the small figures indicate the natural size

and pupates inside the sapwood; eggs are laid on the bark; life-cycle annual, emerging in April, May; emergence-hole elliptical

LITERATURE

Stebbing, 1914 *Ind For. Ins*, p 195, pl xv, fig. 1 (description and coloured illustration of beetle)

Gardner, 1929, *Ind. For. Rec*, xiv, iv, p. 10, pl. iii, fig. 37 (description of larva)

Acmaeodera stictipennis. A bluish-black beetle with 2 reddish or yellow patches on the elytra, length 9 mm., is a borer of *Acacia catechu*, *Adina cordifolia*, *Bauhinia vahlii*, *Cassia fistula*, *C. siamea*, *Shorea robusta*, *Xylia dolabriformis*. It occurs throughout the Indian region. Flight-period April to August.

The cosmopolitan genus **Agrilus** is an enormous assemblage of over a thousand species found throughout the world. The Indian species listed below are small narrow beetles, 4–9 mm. long, black with metallic greenish to purplish reflections.

Agrilus argenteosparsus albizziae, *Acacia gageana*, *Albizzia lebbek*. May–September.

Agrilus aurociliatus, *Grewia tiliaefolia*, *Lagerstroemia parviflora*, April–July and prolonged to October.

Agrilus beesoni, *Albizzia procera*, *A. stipulata*, *Grewia vestita*, *Shorea robusta*. Emergence in April, May and in September–November; generation annual or prolonged. [see fig. 4, No. 39 for beetle, natural size].

Agrilus birmanicus, *Dalbergia sissoo*. May. Beetle, narrow, black with 2 white spots on each elytron, 9 mm. Larva, prothorax narrow and paired spines at end of abdomen.

Agrilus dalbergiae, *Dalbergia sissoo*, May–July.

Agrilus derrisi, *Derris robusta*. April. The larva is described by Gardner, 1929, *Ind. For. Rec.*, Ent., XIV, iv, pp. 119, 120, figs. 48, 51.

Agrilus elaeocarpi, *Elaeocarpus varuna*. April.

Agrilus fici, *Artocarpus lakoocha*, *Buchanania latifolia*, *Ficus glomerata*, *Grewia vestita*. May.

Agrilus gardneri, *Bauhinia vahlii*, *Pueraria tuberosa*, *Millettia* sp. and other climbers. May–July.

Agrilus grewiae, *Albizzia lebbek*, *A. procera*, *A. stipulata*, *Grewia tiliaefolia*, *G. vestita*, *Mallotus philippinensis*. Emergence occurs in April–June, mainly May with prolongation in November–January.

Agrilus jhansinus, *Butea frondosa*. July.

Agrilus malloti, *Mallotus philippinensis*. May, June.

Agrilus niveoguttatus, *Quercus dilatata*. June.

Agrilus pastoralis, *Grewia vestita*, *Kydia calycina*. April, May.

Agrilus pterospermi, *Pterospermum acerifolium*. June.

Agrilus salweenensis, *Xylia dolabriformis*. April.

Agrilus spectabilis, *Alnus nepalensis*. April, May.

Agrilus ventilagini, *Ventilago calyculata*. July.

Agrilus villosostriatus, *Acacia catechu*. May, June.

Agrilus viridifrons, *Grewia tiliaefolia*. December.

The genus **Anthaxia,** also cosmopolitan, includes small beetles, 5–8 mm. long, of blackish-green or bronze colouration. The larva is described by Gardner, 1929, *Ind. For. Rec.*, Ent., XIV, iv, p. 118, fig. 47.

Anthaxia acaciae, *Acacia catechu.* July, August.

Anthaxia acutipennis, *Boswellia serrata, Lannea grandis.* May, June.

Anthaxia angustipennis, *Acacia arabica, Mallotus philippinensis.* April, May.

Anthaxia baconis, *Abies webbiana, Bauhinia retusa, Cedrus deodara, Pinus longifolia, Pyrus pashia, Rhododendron arboreum.* April, May.

Anthaxia beesoniana, *Sindora siamensis.* August in Thailand.

Anthaxia bosei, *Lannea grandis.* May–July.

Anthaxia cailloli, *Pinus longifolia.* June.

Anthaxia gardneri, *Acacia* sp. August.

Anthaxia marshalli, *Dalbergia sissoo.* May. Beetle, oblong, coppery-green, 6 mm. Larva, a "flatheaded borer", 10 mm. See Stebbing, 1914, *Ind. For. Ins.*, p. 213, plate XV, fig. 6 (description and coloured illustration of beetle).

Anthaxia osmastoni, *Pinus longifolia.* May, June.

Anthaxia pinicola, *Pinus longifolia.*

Anthaxia punjabensis, *Pinus longifolia.* May.

Anthaxia semenovi, *Pinus longifolia.* April, May.

Anthaxia sericata, *Bauhinia, vahlii, Mallotus philippinensis, Soymida febrifuga, Terminalia chebula, T. tomentosa.* July, August.

Belionota metasticta, *Swintonia floribunda.* May.

Belionota prasina. A dark bluish-green smooth beetle, with the angles of the pronotum red, length about 25 mm. on the average; length of larva about 60 mm. This is distributed throughout the Oriental Region and in Africa; it is a general wood-borer known from *Acrocarpus fraxinifolius, Anacardium occidentale, Anogeissus latifolia, Buchanania latifolia, Holigarna arnottiana, Hopea parviflora, Lannea grandis, Mangifera indica, M. zeylanica, Psidium guava, Sapium sebiferum, Sonneratia apetala, Spondias mangifera, Terminalia belerica, T. paniculata.* The flight-period is normally April–August, but emergences may continue to November; the life-cycle ordinarily lasts one year and may take two or three years. The larva is described by Gardner, *Ind. For. Rec.*, Ent., XIV, iv, pp. 118–119, figs. 41–44. All stages are figured in *Ann. Rep. Imperial Ent.*, 1917–18, p. 103, fig. 2. [see fig. 34].

Buprestis geometrica, black with reddish or yellow markings, 20 mm. long. [fig. 4, No. 38]. The larva (full grown about 40 mm. long) is a borer of dry *Pinus excelsa* and *P. longifolia* wood. The wood is repeatedly worked through and reduced to fine powdery dust with parts of the autumn wood left as thin flakes here and there. The life-cycle is two years or more with the flight-period in May and June. The larva is described by Gardner, 1930, *Ind. For. Rec.*, Ent., XIV, xiii, p. 281, figs. 12, 13.

Buprestis kashmirensis. A metallic green beetle with ridged

elytra 20 mm. long. *Cedrus deodara*, *Picea morinda*. May, June.

Capnodis carbonaria, in almond and apple trees in Baluchistan and Kashmir.

Capnodis indica. Black with coppery patches, 25-30 mm. long. A borer of logs and stumps of *Pinus longifolia*. April-June.

Capnodis miliaris. Black with a white powdery deposit in the sculpture, 30-40 mm. long; larva about 75 mm. long. Occurs on the North-West Frontier and adjoining western countries. A borer of *Platanus orientalis*, *Pinus gerardiana*, and *Populus euphratica*. April-June. The larva is described by Gardner 1929, *Ind. For. Rec.*, XIV, iv, pp. 116, 117, figs. 45, 46.

Cardiaspis mouhoti. *Chikrassia tabularis*. June-September.

Catoxantha eburnea albiventris. *Sterculia alata*. May. The larva is described by Gardner, 1929, *Ind. For. Rec.*, Ent., XIV, iv, pp. 114-116, figs. 29-34.

The cosmopolitan genus **Chrysobothris** includes metallic beetles, 5-15 mm. long, distinguished by 3 small green circular pits on each elytron.

Chrysobothris andamana. Blackish-green, 12 mm. long; larva about 17 mm. long. A borer of *Shorea robusta* and *Terminalia tomentosa* with an annual generation and prolonged emergence from May to October. The larva is described by Gardner, 1929, *Ind. For. Rec.*, Ent., XIV, iv, p. 118.

Chrysobothris beesoni. Coppery black, 8-13 mm. long. A borer of *Anogeissus pendula*, *Prosopis spicigera*, *Shorea robusta* and *Terminalia tomentosa* has an annual generation emerging in April-August with some individuals carrying over to the following spring. Logs stored in the sun are more liable to attack than those stored in the shade. Attack may take place within 4 months after felling; trees felled 5 to 8 months before the flight-period are liable to attack if stored in the sun but not if stored in the shade.

Chrysobothris gardneri. Coppery black, 12 mm. long. A borer of roots of young *Acacia arabica*, emerging in May-June. A variety is a borer of *Eucalyptus*.

Chrysobothris indica. Metallic black, 12 mm. long. [fig. 4, No. 37]. Bores the wood of *Acacia decurrens*, *Anogeissus pendula*, *Mimusops elengi* and *Myristica longifolia*. May-September.

Chrysobothris sexnotata. Greenish-bronze with violet reflections, 12 mm. long. *Shorea robusta*, May.

Chrysochroa bicolor. *Theobroma cacao*, *Xylia dolabriformis*.

Chrysochroa gratiosa has a transverse white band on rugose green elytra. It breeds in *Sterculia alata*, the close packed tunnels reducing the wood largely to powder. It is on the wing from March to May; the life-cycle is annual. The larva is described by Gardner, 1929, *Ind. For. Rec.*, Ent., XIV, iv, pp. 116, fig. 35.

Chrysochroa opulenta A large beetle, 50 to 60 mm. long,

with purplish-black elytra ornamented with two yellow transverse bands. Bores the wood of *Chikrassia tabularis* and *Lagerstroemia flos-reginae*. The life-cycle is annual with emergence in June.

Chrysochroa sp. An undetermined species of *Chrysochroa*, the larva of which is over 4 inches long, makes tunnels 1/4 to 1/2 an inch deep and 4 to 6 inches wide in concentric planes in the trunk of *Mesua ferrea;* these extend deeply into the wood almost to the centre and completely ruin it. It seems probable that the attack develops in standing living trees.

Chrysochroa vittata see *Chrysochroa opulenta.*

Coomaniella gardneri, *Chikrassia tabularis.* May–July.

Coraebus aurofasciatus. *Quercus lineatus.* June–July.

Coraebus chloropictus. The beetle feeds on foliage of *Glochidion velutinum* in June.

Coraebus cingulatus defoliates *Rubus* spp. and mines the shoot of *Rubus lasiocarpus;* beetles occur June–August. The larva is described by Gardner, 1929, *Ind. For. Rec.*, Ent., XIV, iv, pp. 120, 121; the posterior segment has a distinct fork as in *Agrilus.*

Coraebus conspicuus bores *Symplocos theaefolia.* May.

Coraebus dorsalis attacks the stems of 10–20 year old *Quercus lineata* forming swollen galls, above which the tree dies back. Badly affected cases die.

Coraebus gardneri bores *Echinocarpus dasycarpus.* May.

Coroebina eluta bores *Strobilanthes* sp. in the Anamallais. May.

Cryptodactylus indicus. Black with faint white pubescence, 6 mm. long, *Phyllanthus emblica.* May.

Lampra magnifica. *Protium serratum.* May, June.

Melanophila coriacea. Black, 7 mm. long; larva about 16 mm. long; is a polyphagous borer of dead wood including *Adina cordifolia*, *Bauhinia vahlii*, *Careya arborea*, *Clerodendron infortunatum*, *Ficus religiosa*, *Grewia tiliaefolia*, *Holoptelia integrifolia*, *Lannea grandis*, *Mallotus philippinensis*, *Morus indica*, *Prosopis spicigera*, *Shorea robusta.* Emergence in May–July, the generation being annual or prolonged to two years. The beetles are attracted to forest fires and burnt trees. The larval gallery is a shallow groove on the surface of the sapwood and bast; the pupal chamber is an elongate oval cell with the walls stained black, joined by a short neck to the outside. The larva is described by Gardner, 1929, *Ind. For. Rec.*, Ent., XIV, iv, pp. 117, figs. 39, 40.

Melanophila picta indica. *Populus euphratica.* June.

Psiloptera cupreosplendens. Metallic coppery green, 25 mm.; the beetle gnaws the bark of thin shoots of *Acacia arabica* and *Zizyphus jujuba* in August–October.

Psiloptera fastuosa. Metallic bluish-green, 20–25 mm. [fig. 4, No. 36]; occurs throughout the Indian and Indo-Chinese

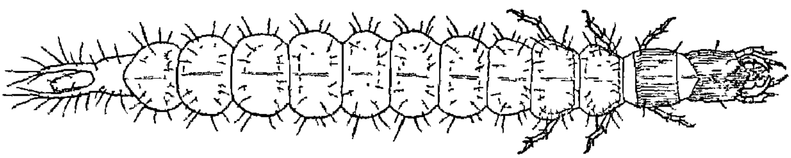


Fig. 35. Larva of Trechus indicus, Carabidae, natural size 8 mm., living in soil.

subregions. The beetle is occasionally very injurious in plantations of *Acacia arabica* and *A. catechu* and of exotics such as *Acacia cyanophylla* where it gnaws the bark off thin twigs in strips and ragged patches during the hot weather; in South India it has been found defoliating *Acacia* in December. The food-plant of the larva is not known but it is presumably one or more species of *Acacia*. Illustrations of the damage done by the beetle are given in Stebbing, *For. Bull.*, No. 12 pl. II, and 1914, *Ind. For. Ins.*, pl. XI (coloured).

Psiloptera viridans in *Terminalia tomentosa*.

Sambus gardneri. *Jasminum dispermum.* April, May.

Sambus gmelinae. Black with a faint pubescence in lines and spots 4 mm. long. *Gmelina arborea.* June.

Sambus nigritus. *Gmelina arborea.* April.

Schoutedenia apicata. *Acacia gageana.* May, June. The larva is described by Gardner, 1929, *Ind. For. Rec.*, Ent., XIV, iv, pp. 113, fig. 38.

Sphenoptera andamanensis. Purplish-black, 10 mm. long. *Lannea grandis*, *Terminalia tomentosa.* May–June.

Sphenoptera aterrima. Black, 10 mm. long. *Cedrus deodara*, and *Pinus excelsa.* April–June. This species has been recorded in previous departmental publications (Hole, 1912; Stebbing, 1914) as a primary sapwood borer of *Cedrus deodara* capable of killing trees. It is now considered to be secondary in its occurrence and an indicator of unhealthy or moribund conditions.

Sphenoptera beesoniana. *Acacia arabica*, dead shoots and rootstocks of young plants. June.

Sphenoptera konbirensis. Violet-black, 13 mm. long; larva about 35 mm. long, in *Terminalia arjuna*, *T. tomentosa.* May, June. The larva is described by Gardner, 1929, *Ind. For. Rec.*, Ent., XIV, iv, p. 117, fig. 36.

Sphenoptera lafertei. Black, 12 mm. long. *Cedrus deodara*, *Prunus avium*, *P. padus.* May, June.

Sphenoptera ? mediocris. *Ailanthus excelsa.* April.

The genus **Sternoçera** includes large metallic green or reddish-brown beetles sometimes used for ornaments and embroidering cloth.

Sternocera chrysis chrysidoides. The beetle eats the leaflets of *Acacia arabica* and *A. leucophloea* and *Inga dulcis* feeding

slowly and continuously so that a string of excrement is almost always hanging from the anus. September, October.

Sternocera diardi, S. laevigata and **S. orientalis** feed on the foliage of *Acacia arabica, A. catechu* and *A. leucophloea* in Central India in the latter part of the monsoon season.

Sternocera sternicornis aequisignata defoliates *Albizzia odoratissima.*

Trachys bicolor, dark bluish. The larva is a leaf-miner of *Butea frondosa* causing large brown blisters on the leaf.

LITERATURE :

Subramaniam P. V., 1920, *Journ. Bomb. Nat. Hist. Soc.*, XXVII, pp. 178, 179. Life history of the buprestid leaf miner, Trachys bicolor Kerr. A pest on Butea frondosa in Mysore.

CANTHARIDAE see MELOIDAE

CARABIDAE

BEETLES of the large adephagous family CARABIDAE, or Ground Beetles, are to be found everywhere from sea-level upto as high a point as the base camp of the Mount Everest Expedition at 16,500 feet. They live in almost every kind of habitat, under stones and logs and the loose bark of trees, in soil and soil-litter, on foliage, in termites' and ants' nests, at the edges of ponds and rivers, in caves and in the desert. It is an attractive family for the collector who wants to specialise on a group of beetles universally encountered ; there are two monographs in the *Fauna of British India* series and a complete catalogue of the species of the Indian region and a separate catalogue of the Ceylonese species, all by H.E. Andrewes (1929, 1935, 1930, 1928).

The majority of species of Carabidae are carnivorous and predators mainly on other insects, arthropods and worms and snails, but some forms eat vegetable matter also, e.g., grain and farinaceous matter, fruit, pollen, etc. They are rarely specific in their choice of food except when the preferred diet is abundant; in times of scarcity they subsist on a great variety of kinds of food, and are able to starve for long periods. Beetles range in size from a few millimetres to two inches, and vary in colour from black to brightly tinctured and patterned. Some forms are apterous and many having vestigial wings are also flightless. Beetles of a few genera protect themselves by discharging a visible irritating vapour. Eggs are deposited in the soil in a cavity dug by the female (*Calosoma, Carabus*) ; some place the eggs on foliage or twigs in mud cells (*Chlaenius*) ; others are considered to oviposit under loose bark attacked by borers.

The larvae are of two types, campodeiform and eruciform. Numerous Indian species have been described and figured by Gardner (1927, 1929, 1933, 1936, 1938). In many genera the larvae live in the soil where they are predaceous on other soil organisms, e.g., *Amara, Craspedonotus, Harpalus, Kareya, Trechus.*

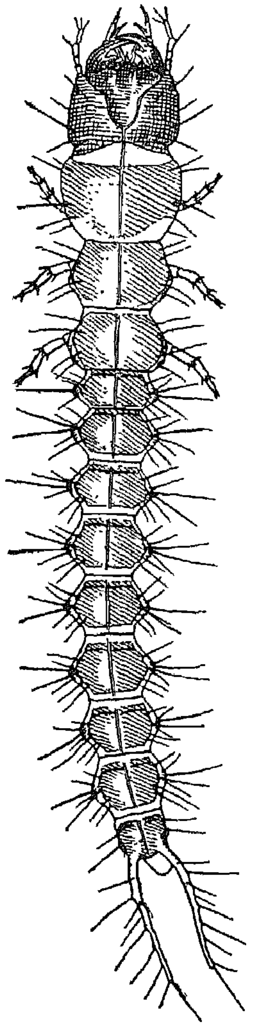


Fig. 36. Larva of *Mochtherus tetraspilotus*, natural size 12 mm., living under bark of trees.

[fig. 35]. Other groups, e.g., *Anthia*, *Broscus* [fig. 37], *Calosoma* [fig. 38], *Chlaenius*, have larvae which are active above ground or in the soil-litter and feed on caterpillars. Others are arboreal in habit, climbing trees and frequenting foliage in search of their prey, caterpillars and larvae of defoliating beetles, e.g., the genera *Calleida*, *Parena*, and some species of *Chlaenius*, which lay their eggs in mud cells on leaves and twigs. Of the truly herbivorous genera no species has been specially studied and very little is known of their importance. Many species have been bred from the logs of trees which were attacked by borers and it is presumed that they are predators of the bark and sapwood fauna, e.g., *Mochtherus*, [fig. 36] *Perigona*, *Tachys* [fig. 41]. Twig-boring cerambycid larvae are preyed on by *Dromius* [fig. 39], which pupates in their tunnels. Some species of *Macrocheilus* and *Orthogonius* [fig. 40] are associated with termites. The pupal period is usually very short. The life-cycle in the types living largely in shelter or concealment is annual but some of the genera with actively hunting larvae may have more than one generation a year. The carabid beetle, which usually feeds on the same diet as the larva, is long-lived, in some cases for over a year.

The economic importance of the carabids as a natural check on the populations of defoliating and soil-living insects is considerable and they form very desirable elements in the predator associations of a pest. Artificial distribution of *Anthia sexguttata* and *Calosoma maderae* [fig. 38] and other species attacking caterpillars of *Plecoptera reflexa* (Noctuidae) has been tried as a control measure in the shisham plantations of the Punjab. Species of *Calosoma* have been used in other parts of the world for biological control.

LITERATURE ON CARABIDAE:

Andrewes H.E., 1919, *Rec. Ind. Mus.*, XVIII, pp. 99-101, Carabidae from Seistan.

— 1921, *tit. cit.*, XXII, iv, pp. 339-348, Carabidae of Barkuda island.

— 1923, *Spol. Zeylan.*, XII, 46, pp. 223-251, New Carabidae from Ceylon I.
— 1924, *Rec. Ind. Mus*, XXVI, 1, Coleoptera of the Siju Caves, Garo Hills, Assam.
— 1924, *Spol. Zeylan.*, XIII, i, pp. 129-141, New Carabidae from Ceylon, II.
— 1928, *tit. cit.*, XIV, 2, pp. 135-195, A catalogue of the Carabidae of Ceylon.
— 1929, *Fauna Brit India*, Coleoptera, Carabidae, I, pp. 431, figs. and pls.
— 1930. *Catalogue of Indian insects*, Part 18, Carabidae, pp. 389.
— 1932, *Journ. Bomb. Nat Hist. Soc.*, XXXV, IV, pp. 862-866, On a collection of ground beetles, Carabidae, from Waziristan.
— 1933. *Ind For. Rec.*, Ent., XVIII, v, pp. 21, pl. 1-iii, Entomological investigations of the spike disease of sandal (8) Carabidae.
— 1935, *Fauna Brit, India*, Coleoptera, Carabidae, II, pp. 323, figs. pls.
— 1936. *Spol. Zeylan.*, XIX, 3, pp. 201-209. New Carabidae from Ceylon, III.
— 1936, *Ind. For. Rec.*, Ent., II, No. 8, pp. 177-180, New Carabidae from India.

Gardner J C.M., 1927, *Ind. For. Rec.*, Ent., XIII, ii,, pp. 63-67, pl. v, Descriptions of three Indian beetle larvae. Carabidae.
— 1929, *tit. cit.*, XIV, iv, pp. 103-108, pl. i, Immature stages of Indian Coleoptera (6).
— 1931, *tit. cit.*, XVI, iv, pp. 91-95, pl. i, *ibid* (9),
— 1933, *tit. cit.*, XVIII, VIII, pp. 1-12, pl. I, ii, *ibid* (12).
— 1936, *tit. cit.*, II, No. 9, pp. 181-198. pl. i-iv, *ibid* (20).
— 1938, *tit. cit.*, III, No. 8, pp. 149-157, pl. i, ii, *ibid* (23).

Numerous species of **Amara** occur, as larvae and beetles in the soil of nurseries and seedbeds of conifers in the Himalayas; some are reported to be herbivorous. The larva of *Amara batesi* is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 9, p. 190, figs. 13, 14.

Anthia sexguttata. A large wingless beetle, black with six big round white spots on the elytra, which occurs in the plains and upland plateaux and particularly in the more arid or desert regions. The adult lives for 8 months or more and hibernates during the coldest season in the soil. It feeds on caterpillars and pupae (e.g., *Dichomeris eridantis, Margaronia pyloalis, Plecoptera reflexa, Pseudophinx discistriga, Tephrina disputaria)* grasshoppers and cockroaches and on beetles of Bostrychidae. It is active from dusk onwards and shelters in concealment during the heat of the day. Eggs are large, white and oval, nearly 1/4 of an inch long and are laid singly and at intervals. The larva is very hairy, black above with the pronotum somewhat reddish and a pair of thick cylindrical processes (urogomphi) at the end of the last abdominal segment. It is described by Gardner, 1939, *Proc. Roy. Ent. Soc. Lond.*, (8) (2), pp. 18-20.

This species was introduced into some of the irrigated plantations of the Punjab in 1938 and 1939 to control the shisham defoliators.

Broscus punctatus, 14-17 mm., is common throughout the whole Himalayas and in the Shan States but does not extend far into the plains. The beetle feeds on caterpillars including large

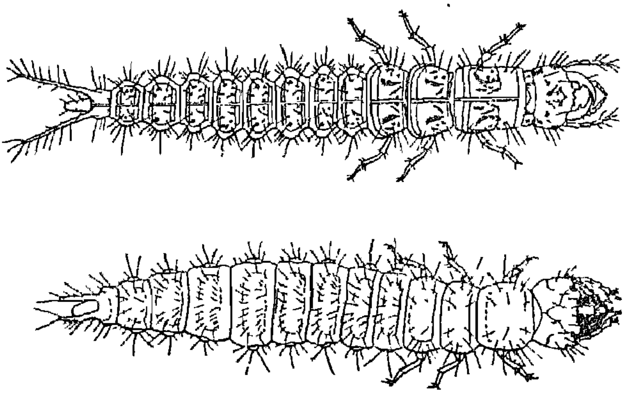


Fig. 37. Above—Larva of *Broscus punctatus*, natural size 22 mm., predaceous on caterpillars frequenting the ground. Below—Larva of *Ophonus indicus*, natural size 17 mm., living in soil.

forms like *Agrotis ypsilon* and *Prodenia litura* (Noctuidae) and *Pieris brassicae* (Pieridae); one or two caterpillars may be eaten daily. The life of the beetle extends for several months. It sometimes appears in extraordinary abundance on the wing in the evenings in March, April. The larva [fig. 37] which lives in sandy soil is described by Gardner, 1936. *Ind. For. Rec.*, Ent., II, No. 9, pp. 185, 186, fig. 15.

Calleida pallipes. The beetle and larva are predaceous on the caterpillar of the bamboo leaf-roller *Pyrausta coclesalis* (Pyralidae). The pupal period is 5 days in August. The larva is described by Gardner, 1933, *Ind. For. Rec.*, Ent., XVII, viii, p. 10, fig. 25.

Calleida rapax. The larva and beetle of this carabid are predaceous on various caterpillars including *Hyblaea puera* (Hyblaeidae), *Hapalia machaeralis*, *Nephopteryx rhodobasalis*, *Pyrausta coclesalis* (Pyralidae). A full grown *rapax* larva is able to kill a caterpillar twice its bulk (e.g., a third instar *H. puera* caterpillar). Pupation takes place in August, September with a pupal period of 5-7 days. An active mature larva may kill one caterpillar every day or two days. The maximum life of the beetle is at least eight months with hibernation (in north India) from the end of November to the end of April. During the active feeding-period the beetle eats one caterpillar every other day. The larva is described by Gardner, 1933, *Ind. For. Rec.*, Ent., XVII., viii, pp. 10, 11, figs. 21, 23.

Calleida splendidula ranges from India to New Guinea. The larva and beetle of this carabid frequent foliage and feed on small caterpillars of various species including *Hyblaea puera*, (Hyblaeidae), *Acharana mutualis*, *Hapalia machaeralis*, *Margaronia*

pyloalis, *Nephantis serinopa*, *Pagyda salvalis*, *Pyrausta coclesalis*, (Pyralidae). The pupal period is four to six days in the monsoon season. The beetle may live for more than a year. During the active season both the larva and the beetle may each eat two or three small caterpillars daily. The larval stages and the pupa are described by Gardner, 1927, *Ind. For. Rec.*, Ent., XIII, ii, pp. 35, 36, figs. 1-5, and 1933, *tit. cit.*, XVII, viii, pp. 9, 10, figs. 20-24.

Calosoma beesoni

This species occurs in deodar forests in the Punjab and United Provinces and is an important enemy of the deodar defoliator, *Ectropis deodarae* (Geometridae). The beetle, 24-25 mm. x 10.5 mm., lays eggs in the soil-litter in the spring; the larvae feed on defoliating caterpillars that fall from the foliage; the beetles climb the trees and feed among the needles attacked by caterpillars. The *Ectropis* pupates at the end of the hot weather in the humus and passes the rest of the year as a pupa. The *Calosoma* larvae feed on the pupae in the ground throughout the rains and spring months, maturing early in the year and pupating in a chamber in the soil. The beetle is able to live for more than a year and can pass long periods without food, which ability permits the species to persist in times when its prey is not abundant. When an outbreak of the defoliator occurs the population of *C. beesoni* increases rapidly in the course of two years and suppresses the pest in the third year. Over 3,000 beetles to the acre occur during an epidemic and scarcely a trace of them can be found where defoliation is not in progress. In forests where the undergrowth is destroyed and the ground is trampled and terraced by excessive grazing unfavourable conditions are created for the existence of *Calosoma* larvae, and in consequence epidemics in grazed or deteriorated forests last for several years unchecked by predators. Descriptions of the larva are given by Gardner and Andrewes; also illustrations of the beetle, etc.

LITERATURE:

Andrewes, H. E., 1929, *Fauna Brit. Ind.*, Col. Carabidae, I, pp. 52-55, figs. 6a, 7a.
Beeson, C. F. C., 1925, *Ind. For.*, LI, pp. 565-572, pl. 31, figs. 1-6.
Gardner, J. C. M., 1927, *Ind. For. Rec.*, Ent., XIII, ii, p. 63, 64, figs. 6-10.
— 1929, *tit. cit.*, XIV, iv, p. 104, fig. 7.

Calosoma himalayanum in Kashmir and Chamba is predaceous on *Lymantria obfuscata* (Lymantriidae). During the pupal period of the host the *Calosoma* larva works through the crowded colonies of pupae on the bark of the trunk and undersurface of branches feeding on the pupae and the emerging flightless female moths and often destroying 100 percent. The larva is described by Gardner, 1929, *Ind. For. Rec.*, Ent., XIV, iv, pp. 104, 105, fig. 6.

Calosoma maderae is a widely distributed and variable species

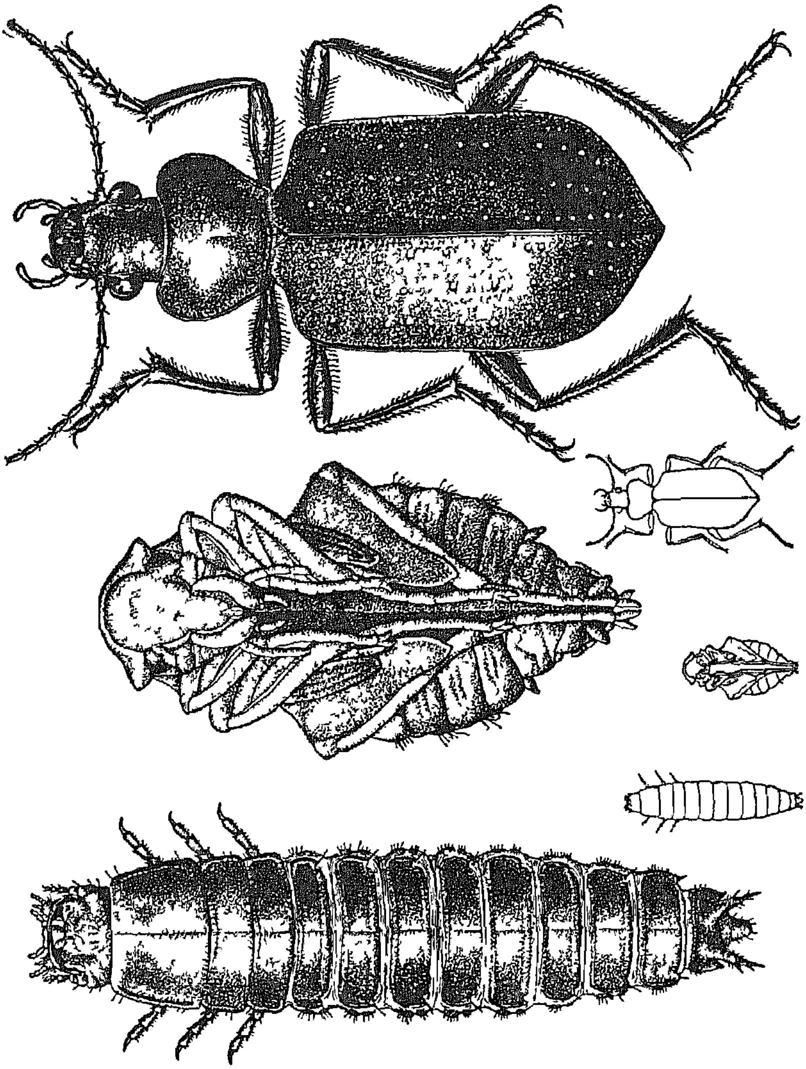


Fig 38 Larva, pupa and beetle of *Calosoma maderae* var. *indicum*: the small figures show the natural size.

extending from Madeira into and throughout the Himalayas in the varieties **auropunctatum**, **kashmirense** and **indicum**. The larva occurs from April throughout the year, at low elevations it may pupate as early as May and produce a beetle after 4 or 5 days pupal period The next generation pupates in October and trans

forms to beetle after 6 days. Both larva and beetle are active hunters of carterpillars. It has been artificially distributed in the irrigated shisham plantations of the Punjab for the control of *Plecoptera reflexa* (Noctuidae).

LITERATURE:
Fletcher T. B., 1919, *Agr. Res. Inst. Pusa*, Bull. No. 89. pp. 33, 34, fig. 26.
Gardner, J. C. M., 1927, *Ind. For. Rec.*, Ent., XIII, ii, pp. 64, 65, fig. 11.
— 1929, *tit. cit.*, XIV, iv, p. 104 (indica).

Calosoma olivieri reported as predaceous on the young hoppers of *Schistocerca gregaria* (Acrididae); it also attacks caterpillars.

Calosoma orientale is predaceous on various caterpillars. Beetles of this species were distributed in some of the plantations of *Dalbergia sissoo* in the Punjab in 1939 to assist in controlling the defoliator, *Plecop'era reflexa* (Noctuidae).

Chlaenius rayotus occurs throughout the Indian region. The beetle and larva frequent foliage feeding on the larvae of Chrysomelidae and on the caterpillars of *Hapalia machaeralis*, *Nephopteryx rhodobasalis*, *Pyrausta coclesalis* and other Pyralidae, Noctuidae, Arctiidae, etc. The larva eats 5 and the beetle as many as 7 caterpillars every two days. It is described by Gardner, 1933, *Ind. For. Rec.*, Ent., XVII, viii, pp. 6–8, figs. 1–6.

Craspedophorus elegans is predaceous on various caterpillars including *Plecoptera reflexa* (Noctuidae).

Dromius eremnus. The larva, 10 mm. long, is predaceous on small twig-boring cerambycid larvae and pupates in their tunnels; it is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 9, p. 195, figs. 42–46. [see also fig. 39].

Harpalus indicola occurs at elevations of 6,000 to 9,000 feet in the Himalayas and frequents the soil of nurseries of conifers. The larva is described by Gardner, 1938, *Ind. For. Rec.*, Ent., III, No. 8, pp. 150, 151, figs. 14–17.

Hypolithus acutangulus, Kareya edentata and **Microcosmus flavopilsosus** feed on caterpillars of *Plecoptera reflexa* and *Tephrina disputaria*. The beetles live for several months.

Macrocheilus niger lives and pupates in termites' mounds. The larva is described by Gardner, 1933, *Ind. For. Rec.*, XVII, viii, pp. 5, 6, figs. 7-13. The pupa has remarkable white mushroom-like projections from the abdomen.

Ophonus indicus occurs at elevations of 5,000 to 6,000 feet in the Himalayas and lives in grass-land and in the soil of nurseries of conifers. The larva [fig. 37] is described by Gardner, 1938, *Ind. For. Rec.*, Ent., III, No. 8, p. 151, figs. 18-21.

Orthogonius duplicatus occurs in termites' nests. The larva [fig. 40] is described by Gardner, 1936, *Ind. For. Rec.*, Ent., II, No. 9, p. 184, figs. 1-7.

Parena nigrolineata occurs throughout the Indian region (excluding the Himalayas) and is predaceous on the caterpillars of *Hapalia machaeralis*, *Margaronia pyloalis*, *Nephopteryx rhodo-*

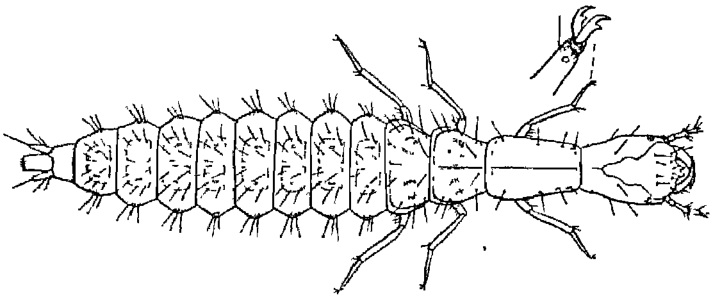


Fig. 39, Larva of *Dromius eremnus*, natural size 10 mm., predaceous on twig-boring Cerambycidae.

basalis, *Sylepta derogata* (Pyralidae) and *Hyblaea puera* (Hyblaeidae) and *Nephantis serinopa* (Xyloryctidae). The beetle discharges a protective gas when alarmed. The larva climbs trees and searches for caterpillars on the foliage. It pupates in May, June and the beetles live through the autumn and winter. The larva is described by Gardner, 1933, *Ind. For. Rec.*, XVIII, viii, pp. 11, 12, figs. 14-19.

Parena rubripicta occurs in South India, Burma and Indo-China, and is predaceous on *Hapalia machaeralis* and *Hyblaea puera*. Its habits are similar to those of *P. nigrolineata*.

Perigona plagiata occurs throughout the Oriental region and passes its life-cycle under the bark of logs of trees attacked by borers and it is presumed that the larva feeds on small insects inhabiting moist decaying bark. The beetle emerges from caged logs in all months of the year and most abundantly in August, September; the life-cycle takes about one year and may be prolonged for two years.

Pherosophus catoirei occurs throughout the Indian region and is predaceous on caterpillars of *Plecoptera reflexa* (Noctuidae) and *Tephrina disputaria* (Geometridae). The beetle lives for several months.

Rhopalopalpus janthinus, north India, feeds on caterpillars of *Plecoptera reflexa* and *Tephrina disputaria*. The beetle lives for several months. The larva is described by Gardner, 1931, *Ind. For. Rec.*, Ent., XVI, iv, pp. 93, 94, fig. 8–11.

Tachys umbrosus lives under the bark of conifers in the Himalayas and is predaceous on bark-beetles (Scolytidae). The larva, 4 mm. long, [see fig. 41] is described by Gardner, 1938, *Ind. For. Rec.*, Ent., III, No. 8, p. 152, figs, 9, 10.

Trichisia morio, north India and Sumatra, feeds on caterpillars of *Plecoptera reflexa*. The larva is described by Gardner, 1927, *Ind. For. Rec.*, Ent., XIII, p. 66, figs. 12–16. The beetle lives for several months.

CERAMBYCIDAE.

Also known as Longicornia or Longhorn Beetles because of the slender segmented antennae that are about as long as or longer than the body. The number of species of CERAMBYCIDAE now known to occur in the Indian region is over 1200 of which 490 belong to the sub-family Cerambycinae and 720 to the sub-family Lamiinae. Over 200 new species have been described since 1914. The food plants of 380 species (156 Cerambycinae, 224 Lamiinae) attacking trees, shrubs, woody climbers and vines are now recorded; these amount to 600 species of plants. An alphabetical index to these food-plants listing the species of Cerambycidae attacking each is given in *Ind. For. Rec.*, Ent., V, No. 1 (1939), pp. 202–227.

The species of tree from which the largest number of Cerambycidae is recorded is *Shorea robusta* with 38. The species of borer having the largest number of food-plants is *Stromatium barbatum* with 311; polyphagy as extensive as this is unusual and is not approached by other species.

Ecology.

Oviposition: The methods used by various species of Indian Cerambycidae for depositing the egg may be allotted to four groups.

Synopsis of oviposition of Cerambycidae

(*a*) on the external surface of the bark in natural cracks or cavities into which the eggs are thrust by the ovipositor; eggs may be laid singly or in small groups, most Cerambycinae, e.g., *Hoplocerambyx spinicornis*, *Xylotrechus smei*.

(*b*) inside the bark in conical cavities or in slits gnawed by the mandibles down to the cambium, into which the ovipositor is inserted so that the egg can be pushed between the sapwood and bast; egg laid singly, e.g., *Blepephaeus nigrosparsus*, *Celosterna scabrator*, *Dihammus cervinus*, *Glenea* spp.

(*c*) on converted wood devoid of bark, in natural or artificial fissures, e.g., *Stromatium barbatum*.

(*d*) in soil, e.g., *Lophosternus hugelii*.

Larval habits: Larval tunnels may be in living trees, or in dead wood, wholly in the bark, in the cambial region, or in bark and sapwood, or penetrate deeply into the heart; some species bore in the pith of slender twigs and green herbaceous stems; also in cones and in the soil; a few start the larval life in a woody climber and later pass into the wood of the tree encircled by it.

Synopsis of location of larval tunnel

(*a*) in slender stems or pith of twigs, e.g., *Apomecyna* spp., *Eupogoniodes* spp., *Sthenias grisator*

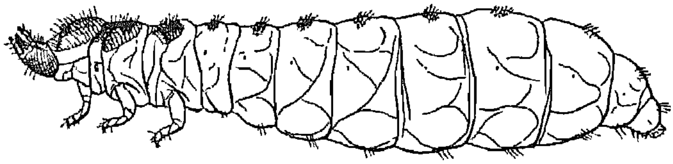


Fig. 40. Larva of *Orthogonius duplicatus*, Carabidae, natural size 25 mm., living in a nest of *Cyclotermes obesus*.

(*b*) in bark, e.g., *Coptops aedificator*, *C. lichenea*

(*c*) under bark or slightly grooving the sapwood, e.g., *Apiocephalus licheneus, Capolymna, Epania calophylli*

(*d*) in sapwood, very many genera

(*e*) in dead heartwood and packed with dust or fibres, e.g., *Macrotoma crenata*, *Remphan hopei*

(*f*) in living heartwood and clean of wood-dust, e.g., *Aphrodisium* spp., *Apriona* spp., *Aristobia* spp.

(*g*) in cones, e.g., *Chlorophorus strobilicola*

(*h*) in soil, e.g., *Acanthophorus serraticornis*, *Lophosternus hugelii*

(*i*) partly in liane and partly in tree, e.g., *Apriona swainsoni*, *Nupserha variabilis*.

Body-form: The usual body-form of the larva is elongate cylindrical; a large head allows the musclature appropriate to powerful mandibles; the body muscles are arranged so as to give firm hold of the walls of the tunnel in order to counterpoise the thrust of the mandibles. The body-form of larvae which bore inside wood is cylindrical and subcircular in cross-section; larvae which bore between the bark and the surface of the sapwood tend to be more flattened or subrectangular in cross-section. Extreme cases of flattening of the body and specialised differentiation from the general type occur in *Apiocephalus* and *Capnolymna*; these extremely flattened larvae feed under dead bark that has contracted away from from the sapwood. Larvae which bore in living tissues tend to have a rougher surface than those which bore in dead tissues owing to the development of minute asperities on the abdominal ampullae and coarse asperities on the pronotum, e.g., in *Batocera*, *Dihammus*, *Nupserha*, *Oberea*, etc.; such locomotory structures are correlated with ability to move freely in open tunnels clean of wood-dust. Some larvae, e.g., the Hippopsini and related groups resemble those of Brenthidae in general facies but not when more closely inspected. The majority of cerambycid larvae live in tunnels which are tightly packed behind with wood-dust but some species keep the tunnels clean ejecting the frass through holes to the outside, e.g., *Aphrodisium*, *Apriona*, *Celosterna*.

Fig. 41. Larva of *Tachys umbrosus*, Carabidae, natural size 4 mm., living under bark and predaceous on Scolytidae.

Some larvae boring in the stems of living plants cause the formation of a gall or canker, e.g., *Dihammus cervinus*, *Melanauster beryllinus*. A few species of Prionini, e.g., *Acanthophorus*, *Lophosternus*, tunnel freely in the soil alongside the roots of trees. Although the aeration of such different larval environments must vary considerably, the spiracles are uniformly annular in the mature larva and annular-biforous in the 1st instar (as Gardner has shown) but there is at least one exception.

Larval food: The group of cerambycids generally termed sapwood borers feed as larvae on the simpler carbohydrates obtainable as soluble sugars and starch; their tunnels are confined to the outer zones of wood rich in these substances, but in some species of wood in which starch is present in the heart the tunnels penetrate throughout. The group of heartwood borers, which includes the prionines and batocerines, feed as larvae on the heartwood digesting its cellulose by means of enzymes, a process further assisted by a proventriculus able to grind the wood-fibres into fine particles. The group of borers of living trees comprises two sections, in one of which the borer kills the attacked portion of the tree or plant or at any rate the tissues surrounding its tunnel, and in the second of which the tunnels are cleaned of wood-dust, etc., and used by the larva for moving about freely; a species of the first section probably has the same feeding-habits as a borer of dead sapwood; a species of the second section has more specialised habits and probably feeds on only selected portions of the wood traversed by its tunnels.

An unusual secretion, possibly associated with digestion, is found in larvae of the Cerambycini; the malpighian tubules secrete large quantities of calcium carbonate that is utilised in constructing a lining or operculum to the pupal chamber (Beeson, 1919, *For. Bull.*, No. 38). [fig. 42].

Pupal chamber: The location and form of the pupal chamber are characteristics of the species but under abnormal circumstances the larva may modify both features, e.g., a pupal chamber normally located in heartwood may be constructed in the bark, or a chamber usually orientated vertically downwards may be horizontal or turn upwards.

The pupal chambers of Indian Cerambycidae can be assigned to seven groups.

Synopsis of pupal chambers of Cerambycidae

Pupal chamber without a specially secreted lining, *(a)* to *(d)*.

Emergence of the beetle by means of the prepupal tunnel, (*a*) and (*b*).

(*a*) Chamber cylindrical or elongate oval, or broadly oval, many genera, e.g., Cerambycini, *Desisa*, *Exocentrus*, *Glenea*, *Leptura*, *Perissus*, *Tetropium*, *Xylotrechus*.

(*b*) Chamber I girder-shaped or dumbell shaped, e.g., *Ceresium* spp., *Gelonaetha hirta*, *Epania calophylli*.

(*c*) Emergence of the beetle by means of an imaginal tunnel from prepupal tunnel, e.g., *Olenecamptus* spp.

(*d*) Emergence of the beetle by means of an imaginal tunnel from the base of the pupal chamber, many lamiine genera, e.g., *Batocera*, *Dihammus*, *Epepeotes*, *Macrochenus*.

(*e*) **Pupal chamber with a specially secreted lining or operculum of calcium carbonate or other material**, e.g., Cerambycini, *Chelidonium cinctum*.

(*f*) **Pupal chamber in a tree encircled by liane in which larva bores**, e.g., *Apriona swainsoni*, *Nupserha variabilis*.

(*g*) **Pupal chamber in soil**, e.g., *Acanthophorus serraticornis*, *Lophosternus hugelii*.

Life-cycle: The length of the life-cycle of Cerambycidae varies within wide limits in India: two and a half months is the shortest period and ten years the longest actually recorded in an insectary—the latter period, however, undoubtedly may be exceeded by several years (others have recorded cases of 13 to 31 years). The annual life-cycle may be regarded as the fundamental rhythm but it is a characteristic of the species rather than of a climatic region or of a habitat. Within the Indian region it is exhibited by species that occur in a temperate climate, and at high elevations as well as by those that occur in the tropics and at sea-level; and by borers of living trees as well as by those of dead wood. In many species the annual cycle is a well marked and fixed characteristic, but numerous more plastic species with a normal annual cycle regularly prolong the life of a part of the brood by multiples of one year up to several years. Divergence from the annual life-cycle is normally in the direction of shortening the period so that two or more generations are completed within a year; in many species the occurrence of a short period is accompanied by the lengthening of the period of part of a brood to 15 or 18 months or even two years with the result that the long-cycle brood is overlapped in time by three or four short-cycle generations. A few species are known in which the minimum normal cycle is more than one year; it is possible that in warmer climates or with more favourable nutritional conditions this period is not required but evidence is wanting.

The life-cycle of Indian Cerambycidae may be allotted to four main groups based on the minimum length of the generation; species attacking living plants are grouped separately from species breeding in dead wood.

Synopsis of generations of Cerambycidae

(1) GENERATION LESS THAN ONE YEAR

(Two or three generations per annum each of which may be prolonged).

(*a*) Borers of living plants—

Apomecyna alboguttata, *Dihammus cervinus*, *Epepeotes luscus*, *Sthenias grisator*.

(*b*) Borers of dead-wood—

Chlorophorus hederatus, *Cycos subgemmatus*, *Dialeges pauper*, *Gelonaetha hirta*, *Mesocacia assamensis*, *Niphona assimilis*, *Olenecamptus anogeissi*, *Xylotrechus smei*.

(2) GENERATION ANNUAL

(*c*) Borers of living plants—

Aphrodisium cantori, *Apriona germari*, *Aristobia approximator*, *Batocera rufomaculata*, *Blepephaeus nigrosparsus*, *Celosterna spinator*, *Chelidonium cinctum*, *Chlorophorus strobilicola*, *Melanauster beryllinus*, *Nupserha variabilis*.

(*d*) Borers of dead wood—

Aeolesthes holosericea, *Coptops aedificator*, *Derolus discicollis*, *Diorthus cinereus*, *Glenea beesoni*, *Hoplocerambyx spinicornis*, *Leptura rubriola*, *Macrotoma crenata*, *Plocaederus ferrugineus*, *Purpuricenus montanus*, *Ropica rufescens*.

(3) GENERATION ANNUAL BUT LIABLE TO BE PROLONGED

(*e*) Borers of living plants—

Pachydissus birmanicus.

(*f*) Borers of dead wood—

Cacia cretifera, *Coptops leucosticticum*, *Demonax balyi*, *Exocentrus alboguttatus*, *Gnatholea simplex*, *Mesosa indica*, *Monochamus bimaculatus*, *Nyphasia apicalis*, *Stromatium barbatum*, *Tetraommatus ocularis*.

(4) GENERATION MORE THAN ONE YEAR

(*g*) Borers of living plants—

Aeolesthes sarta, *Batocera horsfieldi*, *Lophosternus hugelii*.

(*h*) Borers of dead wood—

Nil.

E m e r g e n c e - p e r i o d : The period in which the emergence of cerambycid beetles begins and reaches its maximum is determined primarily by the season of year to which the particular species responds and secondarily by the length of the life-cycle. This is most marked in temperate regions but appears to hold good also for the tropics where there is some difference in the distribution of rainfall throughout the year.

In temperate climates prevalent at high elevations the emergence-period falls almost invariably in summer, influenced also by the fact that in this region the rhythm of the life-cycle is annual. In the submontane regions and in the plains and peninsula of India and Burma the emergence-period may commence in the dry season (usually pre-monsoon), in the monsoon season or in the post-monsoon season ; the greater part of the generation of beetles emerges in the season in which emergence starts although belated individuals may appear out of season.

The emergence-periods of Indian Cerambycidae may be allotted to four groups based on the summer in the mountains, the dry season, the monsoon season (i.e., the south-west monsoon) and the post-monsoon season (or autumn in south India).

Synopsis of emergence-periods of Cerambycidae

(1) TEMPERATE SUMMER EMERGENCE-PERIOD

(*a*) Borers of living plants—

Examples: *Aeolesthes sarta*, *Chlorophorus strobilicola*, *Melanauster beryllinus*.

(*b*) Borers of dead wood—

Criocephalus tibetanus, *Euryphagus lundi*, *Lophosternus hugelii*, *Molorchus hederae*, *Nothorhina gardneri*, *Prionus corpulentus*, *Purpuricenus montanus*, *Trinophyllum cribratum*.

(2) PRE-MONSOON EMERGENCE-PERIOD

(*c*) Borers of living plants—

Apomecyna alboguttata and other species, *Batocera rufomaculata*.

(*d*) Borers of dead wood—

Aeolesthes holosericea, *Diorthus cinereus*, *Eupogoniodes carissae*, *Glenea spilota*, *Niphona assimilis*, *Plocaederus obesus*, *Pothyne acaciae*, *Pterolophia oculata*, *Xenolea asiatica*, *Xylotrechus smei*.

(3) MONSOON EMERGENCE-PERIOD

(*e*) Borers of living plants—

Aphrodisium cantori, *Apriona cinerea*, *Blepephaeus nigrosparsus*, *Celosterna scabrator*, *Dihammus cervinus*, *Sthenias grisator*.

(*f*) Borers of dead wood—

Aesopida malasiaca, *Ceresium leucosticticum*, *Chlorophorus annulifer*, *Demonax ascendens*, *Epipedocera affinis*, *Hoplocerambyx spinicornis*, *Monochamus bimaculatus*, *Perissus bauhiniae*, *Pterolophia occidentalis*, *Stromatium barbatum*.

(4) POST-MONSOON EMERGENCE-PERIOD

(*g*) Borers of living plants—

Apomecyna alboguttata and other species, *Sthenias grisator*.

(*h*) Borers of dead wood—

Niphona assimulis, *Xylotrechus smei*.

Transfer of bored wood from one climatic region to another does not entirely obliterate the characteristic rhythm of the species, if the transfer is undertaken in the mature larval stage or later. It delays or accelerates emergence by a few weeks according to the response of the species to temperature or rainfall in its natural habitat. Thus, *Dihammus cervinus* in Bengal and Assam emerges in April, May; this species in the western United Provinces emerges in June, July. Attacked plants transferred to Dehra Dun from southern Bengal yield beetles at approximately the time they would emerge in Bengal. But the progeny of these beetles reared at Dehra Dun develop according to the Dehra Dun life-cycle. Similarly *Monochamus bimaculatus* in Bengal emerges in April, May but this species in Dehra Dun emerges mainly in June, July. *Hoplocerambyx spinicornis* in Bengal begins to emerge in May, but not till June or July in Dehra Dun. The overwintering generation of *Xylotrechus smei* in Malabar emerges abundantly in April, but this species in Dehra Dun reaches its maximum emergence in May.

Emergence and rainfall: Species of cerambycid borers that begin to emerge at the onset of the monsoon (i.e., group 3) are influenced by the date of arrival of the monsoon, and the quantity and distribution of the rainfall. If the arrival of the monsoon is delayed and precipitation is scanty in the early part of the rainy season the emergence of beetles is correspondingly delayed and prolonged; conversely, in an early and copious monsoon emergence is early and accelerated. The quantity of rainfall required to effect 100 percent. emergence varies with the species. See Part Two, section Climatic Control, for a graphic comparison of the difference in the reponses of *H. spinicornis* and *S. barbatum*, the latter species responding to a smaller quantity of rainfall than the former.

Although the rate of emergence of a generation can be correlated directly with rainfall it is presumed that the immediate stimulus is the atmospheric humidity experienced by the immature beetle in its pupal chamber, since the response is the same if the logs containing borers are sheltered from rain or caged. The atmosphere of the pupal chamber of a borer in a felled tree or dead and dry wood is affected by the moisture-content of the surrounding wood which is raised by absorption of rain-water or from the air. Artificially raising the moisture-content of the wood has the same effect as rainfall and early emergence can be induced by thismeans.

Practically all cerambycid borers, which breed in living plants without killing the plant or the portion tunelled by the larva, emerge in the rainy season; those that kill the plant may depart from this habit. The moisture-content of living wood is at saturation point at all seasons and the atmosphere of the pupal chamber of a borer in living wood is permanently saturated and hence is not affected by external atmospheric humidity. The pupal cell of borers of living trees is, however, usually isolated by thick layers of coarse fibres if in heartwood, or by wood-dust, dead tissues or callus if in sapwood, and possibly is well aerated.

The calcareous operculum [fig. 42] or lining characteristic of the pupal chamber of the Cerambycini is apparently not a device

for regulating the humidity of the chamber since some of the species of this group emerge in the dry season and others in the monsoon.

I m a g i n a l h a b i t s: Many species of cerambycid beetles appear to be able to live without food or water but life is prolonged if water is taken. Some relish fresh sap but are not attracted by it after fermentation, e.g., *Hoplocerambyx spinicornis*. Among the Lamiini beetles of *Apriona*, *Aristobia*, *Batocera*, *Blepephaeus*, *Celosterna*, *Diastocera*, *Dihammus*, *Xylorhiza* gnaw the green epidermis of new shoots, petioles of large leaves, and eat out holes in the blades of leaves; the females also feed when biting out the oviposition cavity.

Sun-loving or diurnally active species frequent foliage and are known to feed on pollen and other parts of flowers, but they do not confine themselves either to the imaginal or the larval food-plant. During the survey of the insect fauna of sandal, *Santalum album*, carried out in Coorg and North Salem, Madras, the beetles of 96 species of Cerambycidae (in 58 genera) were found to frequent the foliage of sandal, and to do so consistently for several months—some species did so for nine months. None of these species feeds in the larval stage in sandal and the majority of the species do not feed as beetles on the bark, leaves or flowers of the tree. The greatest number of species occurred in May with 54 and June with 33 and July with 32.

I m a g i n a l l i f e: The duration of the active imaginal life varies from a few days to several months—*Hoplocerambyx spinicornis* may live about 40 days, *Dihammus cervinus* about 17 weeks, while *Batocera rufomaculata* has lived in captivity for eight months.

E c o n o m i c i m p o r t a n c e: From the synopses in the previous pages it is evident that Cerambycidae are capable of damaging practically every part of the tree except the foliage. Species capable of causing the greatest economic damage are those attacking living trees, e.g., *Aeolesthes sarta*, *Batocera* spp., *Hoplocerambyx*, *Pachydissus*. Species causing technical damage to timber are in the aggregate responsible for considerable losses.

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Ecology of Cerambycidae

DESCRIPTIONS OF BEETLES:

NOTE: A short description is given of the beetle of some species, not in the expectation that the species can be indentified by means of a few adjectives, but as a partial reminder of its colour and markings. The size of the adult is given as an indication of the size of the larva and its borings; for species of which the body-length of the beetle is less than one inch dimensions are expressed in millimetres; for species reaching a maximum length of over one inch dimensions are expressed in inches. Each species is denoted with the symbol **C** or **L**, meaning that it is classified in the Cerambycinae or the sub-family Lamiinae; in many text-books these sub-families are given family rank.

Abryna regis-petri in *Bambusa polymorpha.*

Acanthophorus serraticornis, 2 to 3½ inches, attacks *Bombax malabaricum, Mangifera indica, Morus alba, Shorea robusta.*

This large prionine larva lives in decaying roots of large trees and at intervals leaves the wood and travels through the soil

alongside. When fullgrown it constructs a large oval cell of earth and fibres of wood, smooth inside and rough outside, in which it passes the cold weather months, pupating about April; this hibernation cell is usually formed in the soil. The beetle comes to light and is on the wing between April–September. Fruit trees such as *Mangifera indica* and *Morus alba* are seriously affected. See also Beeson, 1919, *Ind. For. Rec.*, VII, v, p. 16.

Aeolesthes basicornis in *Myristica andamanica* in the Andamans.

Aeolesthes holosericea.

Acacia arabica, Aegle marmelos, Alnus nitida, Anogeissus latifolia, Bauhinia acuminata, Bauhinia retusa, Bauhinia variegata, Bombax malabaricum, Bridelia retusa, Butea frondosa, Careya arborea, Cedrela toona, Chloroxylon swietenia, Cynometra ramiflora, Duabanga sonneratioides, Eucalyptus robusta, Excaecaria agallocha, Ficus bengalensis, Grewia oppositifolia, Hardwickia binata, Kydia calycina, Lagerstroemia parviflora, Lannea grandis, Mallotus philippinensis, Mangifera indica, Miliusa velutina, Morus alba, Myristica andamanica, Ougeinia dalbergioides, Pentacme suavis, Pinus longifolia, Prunus communis, Psidium guava, Pterocarpus marsupium, Pyrus communis, Quercus incana, Sapium sebiferum, Shorea assamica, Shorea robusta, Soymida febrifuga, Tamarix articulata, Tectona grandis, Terminalia belerica, Terminalia myriocarpa, Terminalia tomentosa.

Beetle, C, 4/5ths to 1½ inches, black with a mottled yellowish or silvery short pubescence on the elytra; pronotum intricately wrinkled; antennal segments without spines; in the male the antenna is about 1½ times as long as the body and in the female about as long as the body. [fig. 4, No. 10, male]. This insect is a strongly polyphagous timber borer and is distributed throughout the greater part of the forests of India; it extends up the submontane valleys of the Himalayas to considerable elevations, occurs in the Indus plains and in the Sundarbans, in moist forests and in dry, and in Ceylon, Burma, the Andamans and Nicobars.

Life-history

Eggs are laid in crevices in the bark of dead or felled trees, and never on healthy trees. A female beetle lays about 200 eggs. The egg is about 2·5 mm. long, whitish, and oval with a short stout stalk at one end. The larva bores down into the bast and then begins to excavate a tunnel on the surface of the sapwood. In the course of a few months during the monsoon wide irregular cavities are eaten out of the bark and to a lesser depth in the sapwood. The tunnel is packed with wood and bark fragments and a considerable amount is thrown out through ejection-holes. When mature the larva is about three inches long.

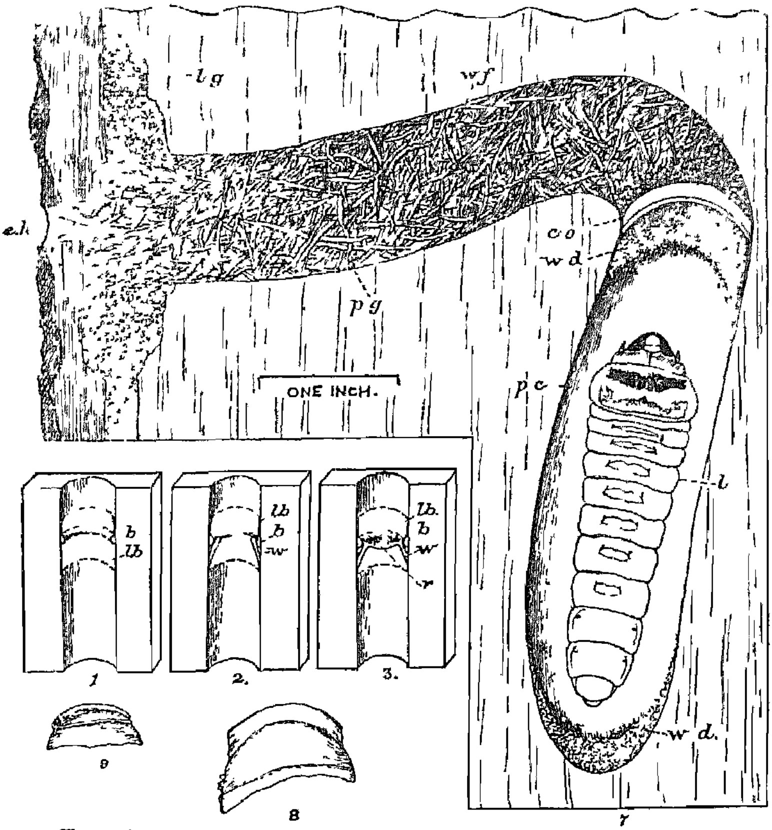

Fig. 42. Pupation of *Aeolesthes holosericea* and *Hoplocerambyx spinicornis.*

No. 7. Longitudinal section through the larval, prepupal tunnel and pupal chamber of *H. spinicornis* in *Shorea robusta*, shortly after construction of the operculum (one inch scale indicates size).—*eh* = ejection hole in bark, *lg* = larval gallery, *pg* = prepupal gallery, *wf* = coarse wood fibres, *co* = calcareous operculum, ridge of the arch, *wd* = wood dust lining the concavity, *pc* = pupal chamber, *l* = prepupal resting larva.

No. 8. Operculum of *Hoplocerambyx spinicornis.*

No. 9. Operculum of *Aeolesthes holosericea.*

Nos. 1, 2, 3. Stages in the construction of the operculum of *Aeolesthes*. *b* = beading, *lb* = lining band, *w* = wall, *r* = roof. (p. 138).

P u p a t i o n · The prepupal tunnel runs in more or less horizontally for 2½ to 3 inches from the sapwood, turns downwards and ends as a vertical chamber. The lower portion of this some 2½ inches long is used as a pupal chamber. [fig. 42, 7]. Before pupating the larva returns to the bark and bites an exit-hole and

clears out the woody debris from the gallery immediately around the entrance to the prepupal tunnel. The outer end of the pupal chamber is closed by a partition of calcium carbonate, which is constructed by means of the following operations. The neck of the gallery in the region of the junction of the pupal chamber with the prepupal portion of the gallery is covered with a thin film of calcareous cement in a band about half an inch wide [fig. 42,1 *lb*] In the central line of the band the larva deposits a beading of nearly semicircular section and about 1/16th of an inch radius and finishes off its surface smoothly [fig. 42,1 *b*]. At a short distance below the beading the larva proceeds to build up the calcareous cement circumferentially in a wall projecting at a slight angle into the lumen of the gallery [fig. 42, 2 *w*]; the wall is carried upwards and away from the wood-surface until its edge impinges on the face of the beading, adheres to it, and receives support from it. As this preliminary structure considerably reduces the cross-sectional area of the gallery, the larva is able to roof in the pupal chamber by filling up the remaining gap with successive concentric deposits each one in a slightly lower plane. The partition when completed is thus slightly convex towards the pupal chamber and concave towards the prepupal gallery [fig. 42, 3 *r*]. The isolated operculum (or rather that portion of it which is easily separable from the wood) forms a cap not unlike a Gandhi cap. [fig. 42, 9].

The larva, now appreciably shrunken. smooths off the roughly excavated wall of the pupal chamber and in the process accumulates a quantity of fine fragments of wood quite distinct from the coarse fibrous strands cut out in the excavation of the prepupal gallery, and also from the irregular fragments of sapwood and bark which pack the sapwood galleries of the younger larvae. This fine dust is compacted against the calcareous cap and may often reach a thickness of ¾rs. of an inch. Pupation occurs in the otherwise empty chamber so produced. The majority of larvae pupate in or about October (in North India) and after a pupal period of three weeks change to beetles. The pupa is about 1¼ inches long.

The immature beetles remain in the chamber through the cold months and emerge in March-May; seventy five percent of the population emerges in April. The life-cycle is normally annual; under adverse conditions a fraction may survive and complete a cycle of two years.

Economic Importance

The large holes, deep in the log, ruin the timber for most purposes. In sal sleepers *Aeolesthes* tunnels are allowed on the same scale as those of *Hoplocerambyx*. This pest may easily become a chronic danger to stored logs in timber-depots, sawmills, and in extensive clear-felling operations. The attack on felled trees does not spread to healthy living trees in the forest. It occasionally occurs in unhealthy standing trees and gradually extends the attacked area year by year till the tree dies. The

beetle is a shade-loving insect and in consquence logs exposed to sunlight are less attractive to the beetle and less damaged by the larvae than are logs lying in the shade. The heaviest oviposition takes place in April and May; eggs may be laid on material felled in any month of the year and within eleven months of felling provided the bark has not dried out too much.

A. holosericea may easily be confused with *Hoplocerambyx spinicornis* in all its stages. In sal forests liable to epidemic outbreaks of the latter species, the presence of *A. holosericea* is usually unrecognised or overlooked because of the similarity of the work of both species in sal timber. The presence in sal timber of well developed larvae (of *A. holosericea*) early in the rains or of immature beetles (also *A. holosericea*) at the beginning of the cold weather gives rise to misapprehensions of a very early brood of *Hoplocerambyx* or to an abnormal two year life-cycle. *Hoplocerambyx* beetles do not occur in the cold weather.

See larval descriptions of both species by Gardner, 1925, *Ind. For. Rec.*, XII, ii, pp. 96, 97, figs. 14, 18, 21, and descriptions of the calcareous opercula of both species [fig. 42, 8, 9] by Beeson, *Forest Bull.* 1919, 38, pp. 2-3, plate 1 and the distinguishing characters given under *H. spinicornis*.

For control measures see Part Two.

Aeolesthes indicola in *Salix* sp.

Aeolesthes induta in *Chloroxylon swietenia*, *Hymenodictyon excelsum*.

Aeolesthes sarta,

Acer cultratum, *Aesculus indica*, *Corylus colurna*, *Juglans regia*, *Platanus orientalis*, *Populus alba*, *Populus euphratica*, *Prunus armeniaca*, *Prunus racemosa*, *Pyrus communis*, *Pyrus malus*, *Salix alba*, *Salix babylonica*, *Salix tetrasperma*, *Ulmus wallichiana*.

Beetle, C, 1 to 1¾ inches, black or dark brown with a fine satiny grey pubescence; it is somewhat more stoutly built than *A. holosericea*. A palaearctic species extending to Baluchistan and Kashmir.

Economic importance: It is particularly injurious to avenue and shade trees planted in towns and along roads, willows and poplars suffering most. It is also a pest in fruit orchards. The avenue and garden trees of Quetta were severely attacked by this borer since 1900. Operations have been conducted against it from time to time during subsequent decades. It has considerably thinned out the roadside trees in Kashmir.

Life-history.

The egg is white, one seventh of an inch long, and is laid in groups of 5 to 10 on living trees in wounds in the bark or on broken ends of branches or in pits gnawed down to the living

bark. About 50 eggs are laid by one female. Hatching takes place in 10 to 14 days. The larva bores in the bast and sapwood. When full grown it is nearly three inches long and 5/8ths of an inch in diameter. The galleries made by the older larvae are broad, deep, excavations packed with woody fibres and fragments. For pupation a wide tunnel is carried into the heart of the tree and at a depth of a few inches turns downwards more or less vertically and is shaped into a chamber about 3 inches long, the walls of which are lined with soft woody felt and the mouth of which is closed by a plug of wood fibres and a calcareous operculum (resembling that of *A. holosericea*) [fig. 42, 9]. The beetle when mature bites its way through the obstructions and passing along the prepupal tunnel bores out through the bark.

The life-cycle at elevations of 5,000 to 9,000 feet ordinarily takes two years. The beetles fly mainly in May; eggs are laid in May and June. The larva is active until the autumn when the approach of the cold weather causes it to become dormant until the following summer. The second season is spent in further tunnelling in the heartwood and the construction of the pupal chamber. The second winter is passed as a pupa or immature beetle remaining in the latter stage for several months until the summer temperature is high enough for emergence.

The tunnelling of the larvae destroys the bast and the living sapwood and the bark dies over the attacked areas and falls away. If the growth of the tree is vigorous and no subsequent attack takes place, callus is formed which overgrows the old tunnels and heals the wounds. Usually attacks recur for several years in succession; the area of killed patches is extended until eventually the sap-conducting zone is completely girdled and the tree dies. A tree may die in two or three years or linger for several years.

For control measures see Part Two.

Aesopida malasiaca in *Acrocarpus fraxinifolius, Bombax malabaricum, Erythrina vespertilio, Kydia calycina, Lannea grandis, Mallotus philippinensis, Mucuna imbricata, Pueraria tuberosa.*

Beetle, L, 9 to 12 mm., speckled grey with black markings mainly in longitudinal streaks. Life-cycle annual with emergence mainly in June–August in north India commencing with the earliest monsoon showers. A sapwood borer. The larva is described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, p. 56 (under the name *Mesosa ominosa* Pasc.); see also 1931, *tit. cit.* XVI, iii, p. 186.

Fig. 43. **Larval tunnels of Buprestidae.**

Log of *Quercus incana*, the bark removed, showing typical buprestid larval tunnels which are shallow grooves in the sapwood and change direction at an angle; the wood-dust filling has fallen out. The oval exit-hole (below) is more compressed on the long axis than in those of Cerambycidae. About ½ natural size.


LARVAL GALLERIES
IN SECTION
PUPAL CHAMBER
LARVAL GALLERY
LARVAL GALLERIES
1
2

Agelasta bifasciana in *Beilschmiedia sikkimensis, Lasiococca* sp., *Litsaea elongata*

Agelasta cristata in *Hevea braziliensis* in Burma.

Agelasta fallaciosa in *Lasiococca* sp. in Bengal.

Agelasta nigromaculata in *Hevea braziliensis* in Burma.

Aglaophis fasciatus in *Quercus lamellosa*. Life-cycle probably twice a year. The larva is described by Gardner, 1931, *Ind. For. Rec.*, XVI, iii, p. 173.

Aglaophis humerosus in *Juglans regia*; two life-cycles a year.

Aglaophis longispinis in *Beilschmiedia sikkimensis, Macaranga denticulata*.

Anaches dorsalis in *Machilus* sp.

Anagelasta apicalis in *Acacia* sp., *Adina cordifolia, Bauhinia vahlii, Buchanania latifolia, Ficus rumphii, Mucuna imbricata, Shorea robusta, Terminalia tomentosa.*

Beetle, L, 8-12 mm., black variegated with greyish to pinkish markings. Life-cycle annual; emergence mainly in June, July. The larva is described in 1931, *Ind. For. Rec.*, XVI, p. 186 (as *Choeromorpha adspersa* Schw.)

Anamera albo-guttata in *Bambusa tulda.*

Annamanum indicum in *Albizzia lebbek.*

Aphrodisium cantori in *Buchanania latifolia, Mallotus philippinensis, Salix tetrasperma* in north India.

Beetle, C, 1 2/5ths to 2 inches, dark metallic green, antennae dark blue or violet; legs dark blue or green with the tarsi fulvous yellow.

L i f e - h i s t o r y: It is a borer of living trees of *Mallotus philippinensis,* usually those of small dimensions (girth about one

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Fig. 44. Damage to wood by Cerambycidae

Borers of the stems of living trees

No. 1. Left side—*Quercus incana* attacked by *Aphrodisium hardwickianum.* Below is a longitudinal diametric section of the bole of the living tree, showing larval tunnels and beetle of *A. hardwickianum.* Above is a transverse section of the same showing distribution of larval tunnels. These are normally empty of wood-dust and their walls are stained black and the surrounding wood is decayed.

No. 2. Right side—*Morus alba* attacked by *Apriona cinerea.* A longitudinal diametric section of the bole of the living tree showing larval tunnels and a beetle of *A. cinerea.* One tunnel runs in the line of the pith for a considerable distance beyond the limits shown in the photograph. The early larval tunnel on the left contains a filling of wood-dust but the majority of the tunnels are empty.

Reduction from natural size is shown by the inch-centimetre scale in each case.

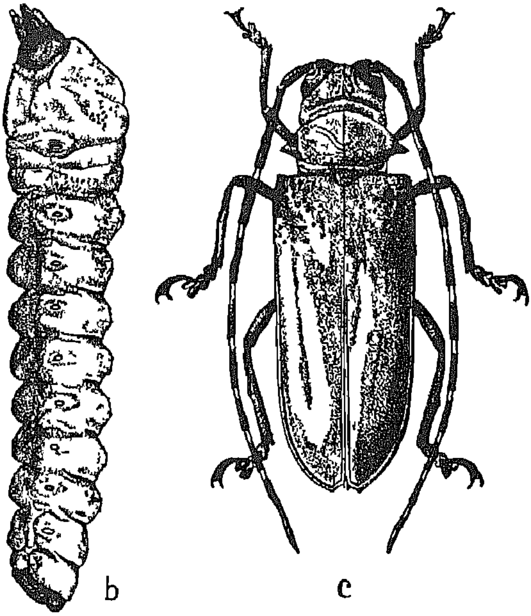

Fig 45. Beetle and larva of *Apriona germari*, natural size; stem of *Artocarpus integrifolia* with larval tunnel and ejection hole (right) in longitudinal section, about half natural size

and a half feet) The larval tunnels run irregularly up and down in the heart of the bole between ground-level and ten feet above ground and reach an individual length of several feet, they are kept clean of frass Ejection holes are constructed at intervals most frequently in the lowest two or three feet of the bole, but also as high as nine feet above ground. The attack is recognisable by the fine brown dust that is thrown out and falls in a heap at the base of the tree The tree is not killed Emergence occurs in the monsoon from July to October, and the life-cycle is believed to be annual

The larva is described and figured by Gardner, 1927, *Ind. For. Rec*, XIII, ii, pp 43 44, figs. 17–18, 23, 24 and 28

Aphrodisium hardwickianum in *Quercus incana*. Beetle, C, 1 1/5th to 1 3/4ths of an inch, metallic green [fig 44, 1]

L i f e h i s t o r y Eggs are laid in the crown and side branches and the upper portions of the stems of living trees The larva

on hatching bores along the branch towards the stem into which it enters and continues the tunnel downwards. The simple tunnel excavated in the early stages becomes more complicated as it reaches branches of greater girth. In the stem the tunnelling is extensive and the accumulated attack of several years removes a great proportion of the wood as the dust is all ejected. Larvae pupate in the stem and beetles begin to emerge with the onset of monsoon. Recent attack is visible by means of ejected frass and crescent shaped exit-holes on the stem; failed attack on branches is indicated by the formation of cankers. The attack of several years eventually kills the tree, and considerably reduces the weight and value of the wood for fuel. Longitudinal and transverse sections of an attacked tree are shown in fig. 44, 1. The life-cycle is believed to be annual.

Apiocephalus licheneus in *Buchanania latifolia.* The larva feeds on the inner surface of the bark which separates from the sapwood. Beetles occur in September-October and January-February. The larva is described in 1931, *Ind. For. Rec.*, XVI, iv, p. 109, plate v, figs. 62-65.

Apomecyna alboguttata in *Benincasa hispida, Lagenaria vulgaris, Luffa acutangula, Luffa aegyptiaca.*

L, 8 to 10 mm., dark brown with round white spots on elytra and prothorax. Beetles emerge in May to September (mainly May and August) from the overwintered generation in dry stems; there are probably one or two more short generations during the monsoon in green material. The larva is described and figured in 1931, *tit. cit.*, XVI, iii, pp. 188-189, pl. iii, fig. 42. (under the synonym of *quadrifasciata* Thomson).

Apomecyna histrio in *Tinospora cordifolia.* The life-cycle of *histrio* is recorded by H.M. Lefroy, 1910, *Mem. Dept. Agr. Ind.*, Ent., Ser., II, 8, pp. 153-155. The larva lives in the living stem of the creeper making irregular tunnels. Beetles of the variety *cretacea* emerged from a climber collected in the Andamans between April and July. L, 10 to 15 mm., brown with large round white spots.

Apomecyna saltator in *Coccinia indica, Cucurbita moschaeta, Lagenaria vulgaris, Luffa acutangula, L. aegyptiaca.* The life-history is recorded by Lefroy, *tit. cit.*, pp. 151-153 coloured plate XVII, (under the name *Apomecyna pertigera*). The beetle feeds on and lays eggs in the stems of living pumpkin and the larva tunnels along the pith and surrounding tissues. The life-cycle is 35 to 45 days in the hot weather with 3 or 4 generations a year. Emergence from dry climbers of the overwintered generation occurs from May to September.

Apriona cinerea in *Debregeasia hypoleuca, Ficus* sp., *Morus indica.*

Beetle, L, 1 3/8ths to 2 inches, ashy grey with numerous black tubercles at the base of the elytra, elytral margins concolorous,

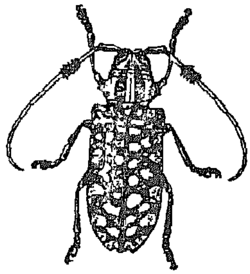

Fig. 46. Beetle of *Aristobia birmanica*, natural size, 5/6ths to 1¼ inch, similar to *Aristobia approximator*.

[fig. 44, 2] occurs in north west India.

L i f e - h i s t o r y : The beetle appears in June–August, and feeds on the bark of living shoots which may be girdled and killed. Eggs are laid in living branches of fig and mulberry but also on dead trees and stumps. The larval tunnel in young mulberry trees runs for several feet up and down the centre of the heart and often extends into the main roots. From the central tunnel short branches communicate through the bark to holes from which wood-dust and reddish sap is ejected [fig. 44, 2]. In small poles there is ordinarily only one active larva and the tree is rarely killed. The life-cycle is annual. It is an occasional pest in plantations. The larva is described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, p. 55.

Apriona germari in *Artocarpus chaplasha*, *A. integrifolia*, *Broussonetia papyrifera*, *Ficus hispida*, *F. infectoria*, *Morus alba*, *M. indica*, *M. laevigata*, *Salix tetrasperma*, *Trema amboinensis*.

Beetle, L, 2 inches, resembles *A. cinerea*, but yellowish-grey, with the elytral sutures and margins bluish grey. Larva 3 inches.

The beetle appears in March to October and has similar habits to those of *A. cinerea*. The larva is described by Gardner, 1931, *Ind. For. Rec.*, XVI, iii, p. 200. [Fig. 45 shows the beetle and larva, natural size; tunnel in stem of *Artocarpus integrifolia*].

Apriona rugicollis in *Morus alba* in Burma; also in *Crataegus cordata*, *Ficus carica*, *Lagerstroemia indica*, *Salix* spp. in Japan where the life-cycle takes 2 years; in Formosa it takes one year. The larva and pupa are described by Kojima, 1929, *Journ. Coll. Agr. Tokyo*, x, pp. 109–115, fig. 2, pl. vi, figs. 4, 5.

Apriona swainsoni in *Butea superba*, *Dalbergia volubilis*, *Tectona grandis*.

Beetle, L, 1 to 1½ inches, tawny brown speckled with white. Larva 2¼ inches.

L i f e - h i s t o r y : The beetle appears in May and lays eggs on the large climber, *Butea superba*, and the larva tunnels in the living stem causing a gall-like swelling. When mature the larva passes from the climber into the tree which is encircled by it at a point where the climber and tree-trunk are in close contact.

Teak up to four feet in girth may be attacked and when the climber remains on the tree for several years with annual attacks of *A. swainsoni*, the damage done is considerable. The gallery in teak is square-bracket-shaped] and may be a foot long and over half an inch in diameter, the oval entrance-hole and wavy tunnel of the larva at one end and the circular exit-hole and straight tunnel of the beetle at the other; it is packed with wood-fibres except in the pupal chamber at one end.

LITERATURE :
Gardner, 1931, *Ind. For. Rec*, XVI, iii, p. 201 (description of larva).
Atkinson, D. J, 1931, *Burma Forest Bull.*, No. 26, p. 7, pl. 1, figs. 6, 9, pl. viii. (illustrations of beetle, larva, damage, biology).
Garthwaite, P. F., 1936, *Forest News Bulletin*, No. 2.
— 1940, *A guide to the borers of the commercial timbers of Burma*, pl. 1.

Aristobia approximator

Adina cordifolia, *Anona cherimolia*, *Anona* sp., *Cassia fistula*, *Cassia renigera*, *Lagerstroemia flos-reginae*, *Peltophorum ferrugineum*, *Pyrus malus*, *Mitragyne diversifolia*, *Mitragyne rotundifolia*, *Tectona grandis*, *Xylia dolabriformis*.

Beetle, L, ¾rs to 1¼ inches, velvety black with large contiguous orange spots, muffs of black hair on third and sometimes fourth and fifth antennal segments. Larva 2½ inches. A Malayan species extending to Assam.

Life-history: The beetle is on the wing during the monsoon and often appears in numbers feeding by day on the bark of living shoots of various trees including exotic species; girdled shoots die back. Eggs are laid on living trees usually on branchlets or shoots of the current year; the female bites a crescent shaped groove in which the egg is deposited. The larva bores from the branch into the main trunk and excavates a long tunnel running downwards for several feet. Several ejection holes are made along the course of the tunnel and frass is ejected in the form of compact, oval white pellets. Pupation occurs at the end of the tunnel and the beetle gnaws its way out by the most direct route; the exit-hole is circular. The life-cycle is annual. It appears to be a pest of fairly young trees and has not been observed in teak over ten years old. Serious damage is caused where it occurs abundantly, as the work in the wood is much more extensive than that of the beehole borer, *Xyleutes ceramica*. In timber the galleries of this borer are usually found only in top logs and near the pith of bottom logs.

Gardner, 1931, *Ind. For. Rec.*, XVI, iii, p. 181 (larva).
Atkinson, 1931, *Burma Forest Bull.*, No. 26, pp. 5, 6, pl. 1, fig. 5, pl. vii (illustrations of beetle and damage, biology).

Aristobia birmanica in *Lagerstroemia flos-reginae*, *Tectona grandis*. The beetle gnaws shoots and the larva tunnels in living saplings in the same way as does *Aristobia approximator*. [Fig. 46]

Aristobia horridula in *Dalbergia paniculata*, *D. volubilis*.

Aristobia octofasciculata in *Santalum album*. Beetle, L, 15 mm., reddish-brown, antennae black with black muffs. Bores the small branches and stems of saplings.

Aristobia testudo in *Lagerstroemia flos-reginae*. Beetle, L, 5/6ths to 1 1/4 inches, similar to *Aristobia approximator*.

Artimpaza dehra in *Phoebe lanceolata*.

Artimpaza bicolor in *Cassia fistula*.

Artimpaza obscura in *Bombax malabaricum*, *Duabanga sonneratioides*.

Beetle, C, 10 mm., glossy, prothorax and abdomen black, elytra pitchy brown with a white stripe along the middle. Life-cycle annual with emergence in April, May. The larva is described and figured by Gardner, 1931, *Ind. For. Rec.*, XVI, iii, p. 174, pl. i, figs. 17–19.

Atimura affinis in *Terminalia tomentosa*.

Atimura combreti in *Combretum decandrum*, *Terminalia chebula*. Beetle, L, 5 to 8 mm. A borer of climbers and small branchwood. Life-cycle annual with emergence in April, May. Gardner, 1931, *Ind. For. Rec.*, XVI, iii, p. 189, pl. iii, figs. 43–45 (description of larva).

Batocera horsfieldi

Alnus nepalensis, *Juglans regia*, *Quercus incana*, '*Salix tetrasperma*, *Trema amboinensis*.

Beetle, L, 1 5/6ths to 2½ inches, black with fine ashy or yellowish-grey pubescence, pronotum with 2 elongate white or yellowish spots, elytra with numerous shining black tubercles at the base, and several rounded or broken elongate white marks extending to the truncate apex, scutellum white or yellowish. Larva, 6 inches. A borer of living trees and a pest in walnut and alder plantations in the Darjeeling Himalayas, and of oak in the Kumaon Himalayas.

L i f e - h i s t o r y : The egg is laid on the bark of the living tree usually within the basal four or five feet of the bole, but a tree that is very heavily attacked may have tunnels as high as ten feet (rarely 20 feet) from the ground. The larva on hatching bores down to the surface of the sapwood and excavates a shallow, more or less circular patch from which a relatively enormous tunnel is later bored upwards into the centre of the heartwood. The tunnel gradually expands in diameter and reaches a length of 18 inches or more and a width of two inches. The fragments of wood resulting from its construction are thrown out through an ejection-hole in the sapwood chamber, which is marked by a blackened scar and some exudation of blackish sap and frass on the bark. Its upper end is considerably widened into a pupal chamber and is not very far from the bark. The shreds and fibres of wood produced by the final excavation before pupation are 1½ to 6 inches long and loosely fill the heartwood tunnel. The full grown larva is nearly six inches long. The beetle escapes by boring an exit-tunnel through the intervening inch or so of wood and leaves a circular exit-hole about one inch in diameter.

The length of the life-cycle is unknown; it may take two or three seasons. Beetles occur in September–October and possibly emerge earlier. There is one generation a year in *Paulownia tomentosa* in Japan, the beetles emerging from June to August near Tokyo.

Trees of *Juglans regia* of six inches diameter and upwards are liable to attack; ordinarily the infestation is limited to one or two tunnels near the base of the tree but as many as 16 tunnels may occur in a 20 foot length of bole. In *Quercus incana* the tunnels are confined to the basal 3 to 5 feet of the bole. Attacked trees are not killed and their vigour is apparently not seriously affected. Where the beetle is abundant every tree in a stand is attacked even in mixed crops. The timber is spoiled for all purposes except firewood and is heavily depreciated in value.

Batocera lineolata in living *Quercus griffithi* and *Q. serrata* in Burma. It attacks 8 species of *Quercus* and *Castanea sativa*, *Fagus japonica* and *Ulmus americanus* in Japan where the life-cycle lasts two years (Kojima, 1929).

Batocera numitor in *Anthocephalus cadamba*, *Hodgsonia heteroclita*, *Lannea grandis*, *Mangifera indica*, *Ochroma lagopus*, *Sterculia villosa*.

Beetle, L, 1 2/3rds to 2 5/6ths of an inch, rusty brown with light brown or yellowish pubescence, pronotum with narrow or triangular spot of dark orange, scutellum white, elytra with four or more inconspicuous dark orange spots [see fig. 49, No. 1].

Life-history: It attacks living trees that are not in good health or have been injured. Eggs are laid on wounds or parts of the bark having no strength to resist the tunnelling of the larvae. In small branches the tunnel is carried deep into the wood and continued longitudinally parallel to the axis of the branch or bole; from the main tunnel branch tunnels communicate with ejection-holes in the bark from which sap and wood-dust ooze out. When heavily attacked a great deal of the sapwood is destroyed and branches or small trees may be killed. In large branches or trunks a prepupal gallery runs in for about 3 inches and turns at right angles into the pupal chamber which is about 1 5/8ths by 5 or 6 inches, with a plug of long wood-fibres at its upper end. The prepupal tunnel and pupal chamber are illustrated in fig. 49, 1. The life-cycle in the lowlands is probably annual with beetles occurring during the monsoon but emergence occurs from dry wood in most months of the year. The beetle is figured by Stebbing, 1914, *Ind. For. Ins.*, pp. 367–370, figs. 245–247, under the name of *Batocera titana* (figs. 245 fem., 246 male).

Batocera roylei in *Mangifera indica* in north India and Burma.

Batocera rubus in *Alstonia scholaris*, *Artocarpus integrifolia*, *Castilloa elastica*, *Erythrina indica*, *E. lithosperma*, *Ficus elastica*, *Ficus hispida*, *Ficus infectoria*, *F. tjakela*, *Mangifera indica*, *Ochroma lagopus*. Widely distributed in the Oriental Region.

Beetle, L, 1 1/5th to 1 9/10ths of an inch, dark with an olive brown vestiture, pronotum with 2 kidney-shaped yellowish patches, scutellum white, elytra with shining granulations at base and four

or more white spots of variable size on each elytron. This species is figured by Stebbing, 1914, *Ind. For. Insects*, p. 366, fig. 244, under the name of *Batocera albofasciata*. The species previously known in literature as *B. rubus* Linn. is now referred to *B. rufomaculata* De Geer.

Batocera rufomaculata.

(*a*) subspecies **rufomaculata** in **Adina cordifolia*, *Albizzia lebbek*, *Artocarpus integrifolia*, *Barringtonia acutangula*, *Bauhinia acuminata*, *Bombax malabaricum*, *Broussonetia papyrifera*, *Buchanania latifolia*, *Carica papaya*, **Cocos nucifera*, *Dalbergia sissoo*, **Dyera costulata*, *Erythrina indica*, *Eugenia jambolana*, *Ficus bengalensis*, *Ficus carica*, *Ficus elastica*, *Ficus glomerata*, *Ficus infectoria*, *Ficus religiosa*, *Ficus tjakela*, *Garuga pinnata*, *Hevea braziliensis*, *Lannea grandis*, *Mangifera indica*, *Moringa pterygosperma*, *Morus indica*, *Platanus orientalis*, *Semecarpus anacardium*, *Shorea robusta*, *Spondias mangifera*, *Sterculia colorata*, *Sterculia villosa*.

Beetle, L, $1\frac{1}{2}$ to $2\frac{1}{4}$th inches, dark with a fine greyish vestiture, pronotum with 2 kidney-shaped orange-yellow spots, scutellum white, elytra in basal third with numerous black tubercles, and several yellowish spots variable in number and shape. [see fig. 48] Stebbing illustrates five variations in the elytral spot-pattern in (1907) *Forest Bull.*, No. 10 and (1914) *Ind. For. Ins.*, plate XXVI. Miller, 1936, *Malayan Forester*, v, pp. 158, 159 describes the beetle. Larva, full grown 4 inches. Widely distributed in the Oriental Region.

Life-history: The beetles are nocturnal and feed to some extent by gnawing the bark of living twigs or eating the green tips particularly of *Ficus* spp. The female lays up to 200 eggs placed one by one in incisions cut in the bark with the mandibles. Oviposition normally takes place on dead trees but also on the branches and trunks of living trees that are not in good health and on the roots of trees exposed by erosion, etc. Blazes and wounds and panels produced on rubber trees and *Dyera costulata* (in Malaya) by tapping for latex are sites of successful oviposition. Living trees such as figs, rubber and semul may be attacked year after year at the margins of earlier borings and the area of injury is gradually extended till the tree succumbs; often a branch breaks or the trunk gives way weakened by numerous tunnels.

The egg is a brownish-white cylinder, 6 × 2 mm., with narrowly rounded ends. The newly hatched larva is about 10 mm. long; it feeds at first in the meristem and later penetrates deeper. The larval excavations in the early stages are extensive, irregular and deep in the sapwood. They are packed with very coarse chips and fibres of wood and bark; the bark is often completely hollowed out so that it splits and breaks away leaving the packing of the tunnels exposed. The tunnels in the depth of the wood are irregular and one or more inches in cross-section. The pupal cham-

ber is a 2 to 3 inch cavity in a widened extension of part of the larval gallery and is surrounded by long interlaced fibres.

[See fig. 48 showing prepupal tunnel and pupal chamber]. This chamber is prepared in the cold weather and occupied by the larva in a resting condition until about March or April; in this stage the larva is bright yellow without any food in the alimentary canal. The pupal period lasts for three to four weeks and is followed by an immature beetle stage of variable duration. The beetle emerges by a short tunnel running direct to the exterior and ending in a circular exit hole. The emergence-period in north India is from March to August; 50 percent of the beetles emerge in May and 30 percent in June. The life-cycle is thus annual. The life of the beetle is considerable and the maximum life recorded in captivity at Dehra Dun is eight months.

Browne and Foenander, 1937, *tit. cit. infra.* p. 245, consider the life-cycle in Malaya may be completed in six months. This would be possible in view of the long adult life without excluding an annual cycle as normal.

LITERATURE:

The larva and pupa are described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, i, pp. 23, 24, plate iv, figs. 62—64 and by Miller, 1936, *Malayan Forester*, pp. 157, 158, figs. 1—13. This species is generally referred to and frequently figured in entomological literature under the name of *rubus* or *rubra*: e.g. Stebbing, 1907, *Forest Bull.* No. 10, The Duki fig tree borer of Baluchistan. most of which is republished in 1914, *Ind. For. Insects*, pp. 362-365, plate XXVI; Browne and Foenander, 1937, *Malayan Forester*, vi, pp. 240-254, figs. 1, 2, plate 1, 2, An entomological survey of tapped jelutong trees.

(*b*) subspecies **andamana** in *Canarium euphyllum, Ficus bengalensis, Parishia insignis.*

Blepephaeus modicus in *Santalum album.* Beetle, L, 17 to 24 mm. Small branches are bored; the tunnel runs longitudinally in the heart and is filled with fine dust.

Blepephaeus nigrosparsus in *Clerodendron infortunatum* in the United Provinces.

Beetle, L, 15 to 22 mm., obscurely marked with greyish and brownish colours and black speckling, a borer of living *Clerodendron* plants, developing in the rootstock and the base of the stem, particularly in the hard twisted and knotty roots (The common *Clerodendron* borer, *Dihammus cervinus*, more often develops in the soft young root and stem-tissue). The emergence-period of the beetle is June, July. The beetle feeds by gnawing the bark and skin of the current year's growth of the plant. The egg is laid in a shallow longitudinal incision gnawed in the green bark of the stem and the larva hatches in five days and bores at once downwards into the bast, and in the course of a few weeks makes its way down into the roots. A coppice-shoot may die back if girdled but the root-stock is not killed. The beetle emerges through an oval exit-hole in the root near soil-level. The generation is annual.

Cacia cephalotes in *Quercus spicata.*

Cacia cretifera. *Acrocarpus fraxinifolius, Albizzia odoratissima, Bauhinia retusa, Berberis asiatica, Clerodendron infortunatum, Dalbergia sissoo, Ficus* sp., *Flemingia semialata, Indigofera tinctoria, Lannea grandis, Mallotus philippinensis, Ougeinia dalbergioides, Pterocarpus marsupium, Ricinus communis, Shorea robusta.*

Beetle, L, 11–12 mm., black with an irregular pinkish transverse band across the elytra, antennal segments with muffs of black hairs. Larva 20 mm. A borer of dead sapwood and dry sticks. The life-cycle is annual with emergence in June (23 percent) and July (51 percent) but is capable of being extended for two years so that emergence may occur from May to October. The larva is described in 1931, *Ind. For. Rec.*, XVI, iii, p. 187, fig. 32.

Cacia ornata in *Butea frondosa.*

Camptocnema lateralis in *Bombax insigne, Mangifera indica.*

Celosterna scabrator.

Acacia arabica, A. catechu, Cassia siamea, Casuarina equisetifolia, Pithecolobium dulce, Prosopis juliflora, P. spicigera, Tectona grandis, Zizyphus jujuba.

Beetle, L, 1¼ to 1½ inches, dull, yellowish-brown, the sides of the body and legs bluish, elytra yellowish-grey with a large number of black spots varying in size from a pin's head to minute specks. The form attacking babul and most of the other known hosts in India is the variety *spinator*, which differs from the typical form in having the tawny or brownish, close, short pubescence broken up on the elytra by a background of light grey. [fig. 4, No. 6 and fig. 47].

Life-history: The insect is most notorious as a pest of babul, *Acacia arabica*, in Berar (since about 1890) but has also been recorded as injurious in plantations of casuarina and teak and of *Prosopis spicigera*. Eggs are laid on young living plants and the larva bores in the stem and the roots which are hollowed out. The growth of the tree is stopped and it frequently dies back.

Emergence-period: The emergence of the beetle begins with the onset of the monsoon, and a heavy fall or continuous rain for two or three days accelerates emergence for the following week, while a rainless interval slows it down. In babul in Berar the average rate of emergence has been determined to be:—

5	percent	emerged	by	the	beginning of July.
30	,,	,,	,,	,,	middle of July.
65	,,	,,	,,	,,	end of July.
77	,,	,,	,,	,,	middle of August.
87	,,	,,	,,	,,	end of August.
99	,,	,,	,,	,,	end of September.
100	,,	,,	,,	,,	middle of October.

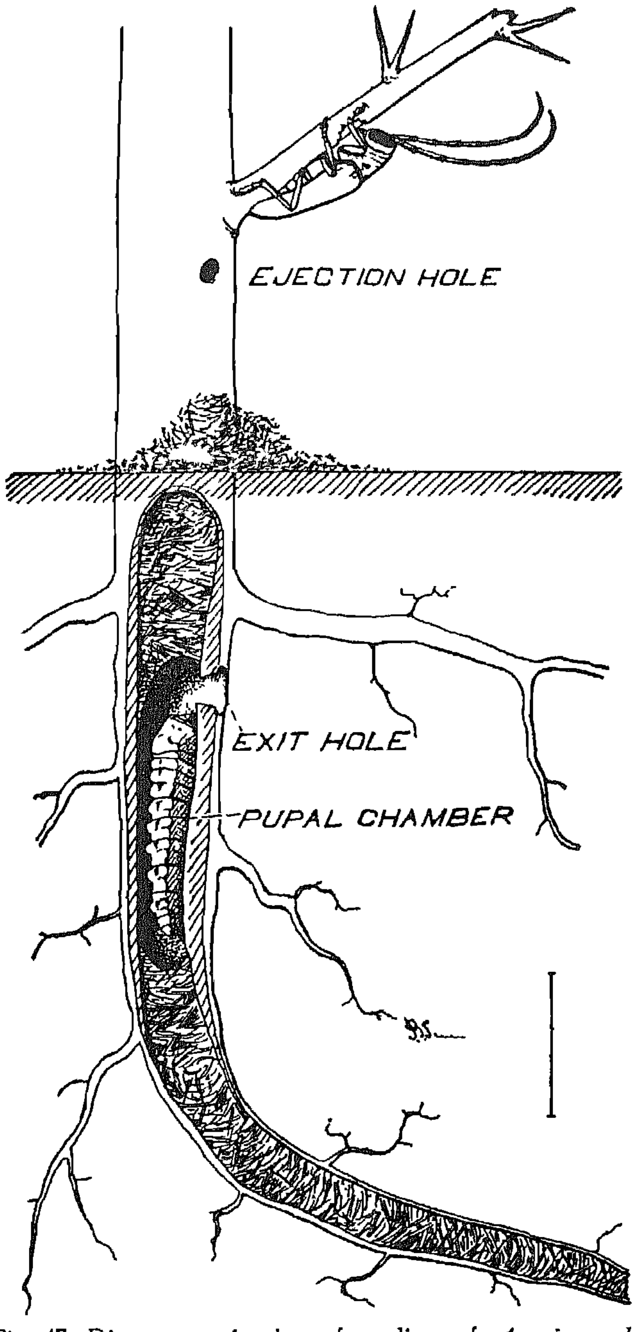

Fig. 47. Diagrammatic view of sapling of *Acacia arabica* showing larval tunnel, pupal chamber and exit-hole of *Celosterna scabrator* in root, and beetle gnawing bark of branch. Vertical scale-line represents one inch.

L o n g e v i t y : The beetle has a normal expectation of life of about 45 days for both sexes; some individuals may live 80 days. Consequently the beetle-population reaches its maximum in the forest during the latter half of August and rapidly decreases during September, since the death-rate greatly exceeds the emergence-rate. By the end of September it has been reduced to one third and by the end of October to possibly one tenth. A few survivors may be met with during November and December. See Beeson, 1931, *Ind. For. Rec.*, XVI, ix, pl. ii, for graph of emergence.

F e e d i n g - h a b i t s : The beetles feed voraciously mainly at night on the bark of young living shoots, scraping it away with the mandibles down to the surface of the wood in irregular patches and bands, so that the shoot is completely girdled and killed back. [fig. 47]. The height-growth of the plant is counteracted and it remains bushy and stunted. The plants eaten by the beetle are *Acacia arabica*, *Casuarina equisetifolia*, *Pithecolobium dulce*, *Prosopis juliflora*. *Shorea robusta*, *Tamarix indica*, and *Zizyphus jujuba*; it is also recorded on cotton. In pure babul plantations the chief breeding-grounds of the borer are in the young coupes three to seven years old especially on dry soils.

O v i p o s i t i o n : The eggs are laid in young living plants, in stems having a minimum basal girth of two inches and a maximum of nine inches. Above this dimension the bark is too hard for the insertion of the egg and too dry for the hatching of the larva. Ordinarily no more than one egg is laid per stem and only one insect matures in each stem. The egg which is about 5 × 2 mm., is forced through a horizontal incision made within six inches of ground-level and is deposited under the bark and the incision is sealed with a secreted cement. The number of eggs laid by each female is small, possibly 20 to 40, and the oviposition-period extends for several weeks. The egg hatches in 2 to 3 weeks.

L a r v a : The newly emerged larva is about ¼ of an inch long; the mature larva is about 2½ inches long. It is described in 1927, *Ind. For. Rec.*, XIII, i, p. 52, figs. 41–43 and 46; idem p. 53, fig. 47 (pupa). On hatching the larva feeds on the soft tissues around the

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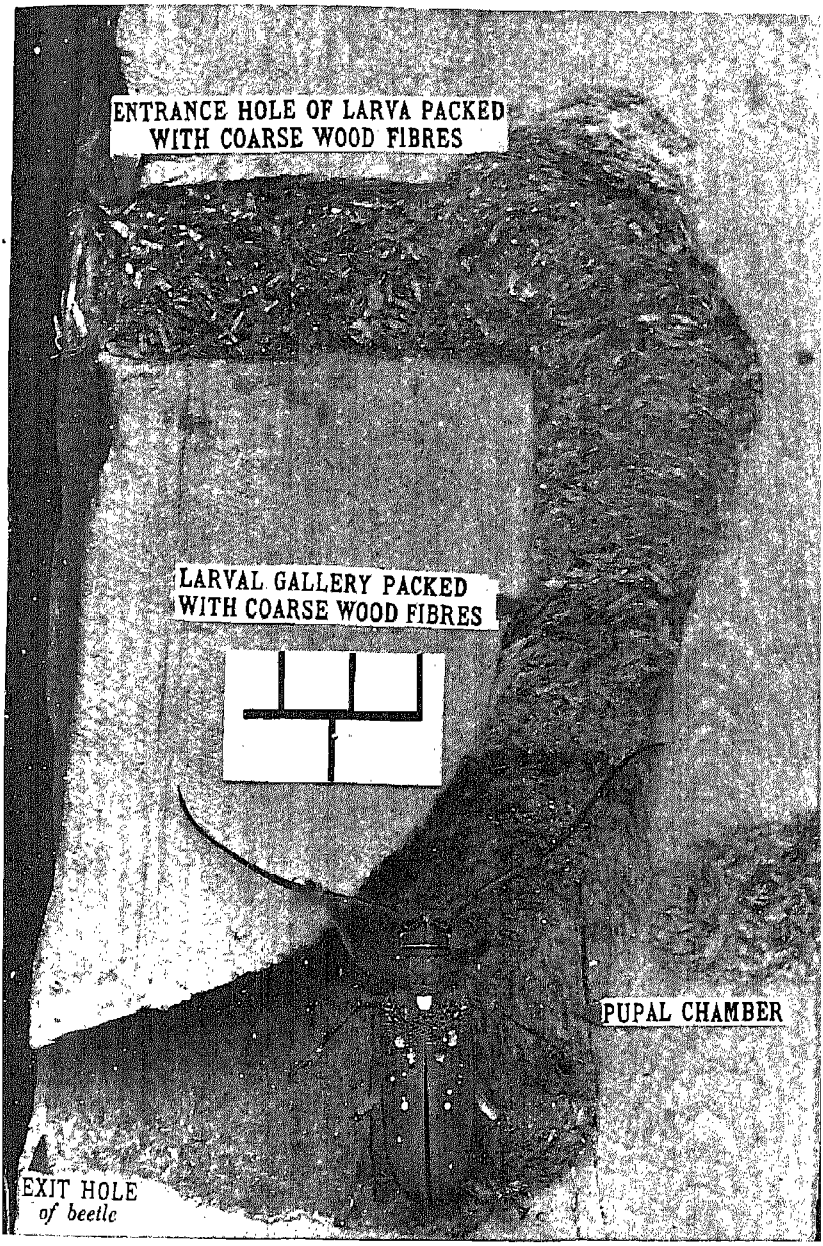
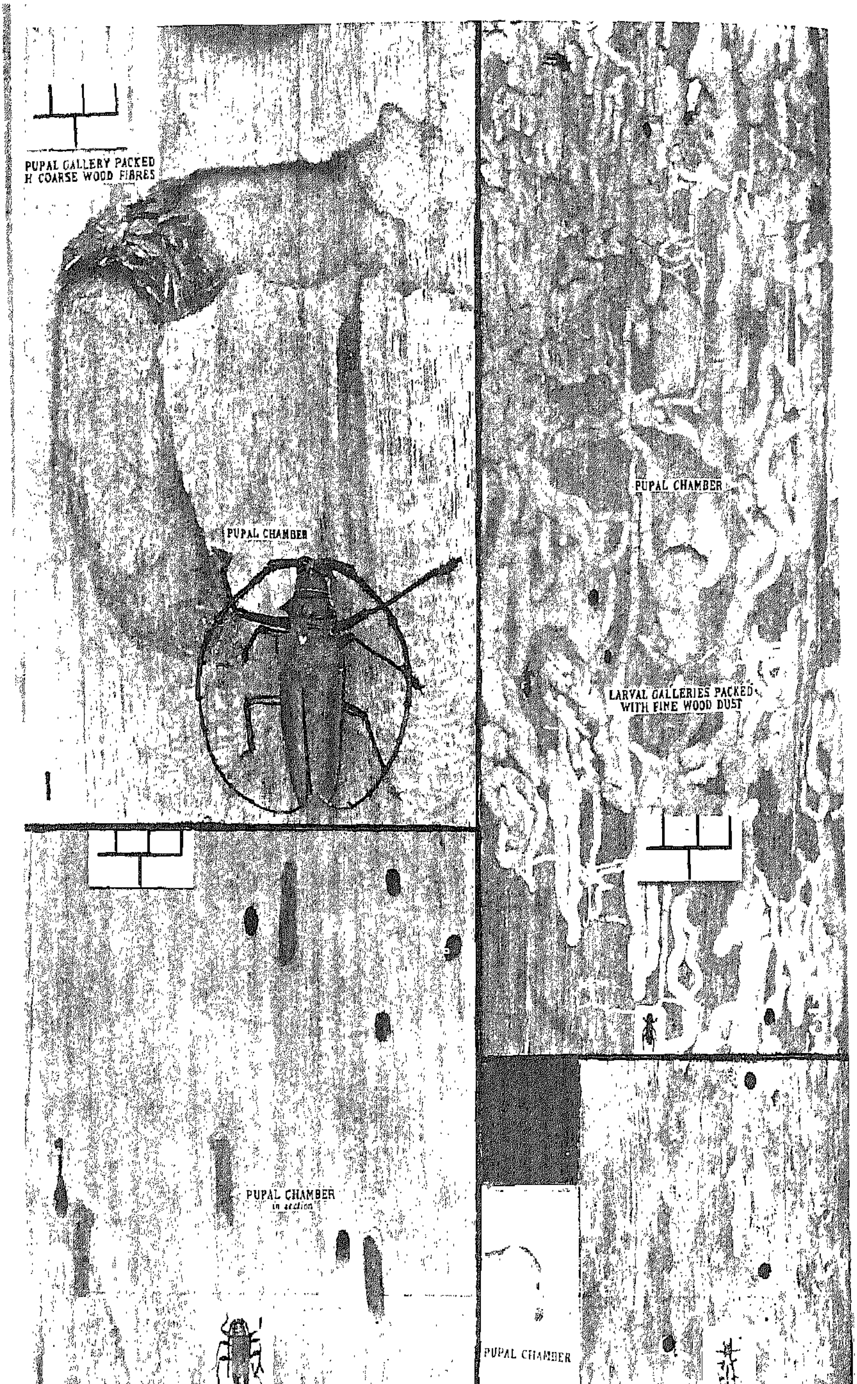
Fig. 48. Pupation tunnel of Batocera rufomaculata

Longitudinal section of log of *Ficus infectoria* showing tunnel of mature larva and pupal chamber and exit-tunnel of *Batocera rufomaculata*. Above is the prepupal tunnel running inwards from the sapwood (on left) and then downwards, packed with very coarse wood-shavings; below is the pupal chamber free of packing except for a lining of finely chewed wood-particles; the extension to the bottom left is the exit-tunnel cut through by the emerging beetle.

The illustration is natural size as indicated by the inch—centimetre scale.


ENTRANCE HOLE OF LARVA PACKED WITH COARSE WOOD FIBRES
LARVAL GALLERY PACKED WITH COARSE WOOD FIBRES
PUPAL CHAMBER
EXIT HOLE
of beetle



PUPAL GALLERY PACKED
H COARSE WOOD FIBRES
PUPAL CHAMBER
PUPAL CHAMBER
LARVAL GALLERIES PACKED
WITH FINE WOOD DUST
PUPAL CHAMBER
in section
PUPAL CHAMBER

oviposition-cavity and then bores into the centre of the stem and works downwards. The frass produced while tunnelling is ejected through a hole in the stem and within a month sufficient has accumulated to form a noticeable heap at the base; in two and a half months the heap is large and conspicuous enough for attacked trees to be recognised at a distance [fig. 47]. During its feeding-period the larva works up and down enlarging the tunnel and extending it in the main root to a total length of about two feet. In thin stems and roots of about the thickness of one's finger the tunnel is kept clean of wood-dust, but in thicker stems much of the excavation is packed with wood-dust and fibres. The length of the larval period is about nine or ten months. A pupal chamber is prepared in the hot weather—a cell two to three inches long surrounded by long fibres [fig. 47].

The pupal period is about 15 to 17 days. The beetle emerges by eating a circular hole through the bark, usually just below ground-level and invariably far below the site of the ejection-hole of the larva. The life-cycle is thus annual.

Economic importance: The effect of this damage on the tree is shown by a complete cessation of growth which, in the case of weak plants, is followed by the death of parts above

Fig. 49. Damage to wood by Cerambycidae

No. 1. *Batocera numitor*—Longitudinal section through log of *Sterculia villosa* showing tunnel of mature larva from which the packing of coarse wood shavings has fallen away except just at the mouth of the pupal chamber, which is empty; the exit-tunnel of the beetle has not been constructed—it would run from the bottom of the chamber towards the right. A male beetle of *B. numitor* is added.

No. 2. *Nyphasia apicalis*—The tangential face of a plank of *Anogeissus latifolia*, showing larval tunnel, pupal chamber and beetle of *N. apicalis*: the larval tunnels appear in cross-section as short ovals and the pupal chambers are cut in longitudinal section and show their upper and lower bulbous ends filled tightly with fine wood-dust.

No. 3. *Clytus minutus*—The surface of the sapwood of a log of *Tectona grandis*, after removal of the bark, showing the larval tunnels and entrances to pupal chambers of *C. minutus*; the larval tunnels are tightly packed with fine wood-dust; above are cocoons of its parasite; below is a specimen of the beetle.

No. 4. *Olenecamptus indianus*—the surface of the sapwood of a log of *Anogeissus latifolia*, after removal of the bark, showing exit-holes of *O. indianus*; below is a specimen of the beetle; at the left is a pupal chamber in longitudinal section.

All illustrations are to the same scale which is half natural size, as indicated by the inch-centimetre scales.

ground. A vigorous plant may make growth at a faster rate than the larva destroys it, and if the larva dies, such a plant will rapidly heal the external wounds with callus and copious exudation of gum. In localities where babul is grown on unsuitable soil, an incidence of attack of up to 80 percent has been recorded.

C. scabrator is practically immune from parasitism and predator control in the larval and pupal stages; bacterial disease is infrequent; the extensive babul plantations of Berar offer a very favourable food-supply. Nevertheless the pest has not multiplied to a permanent epidemic characterised by 100 percent attack. The biotic factors preventing excessive multiplication appear to be (*a*) low reproductive potential, (*b*) restriction of larval stage to one individual per young stem, (*c*) destruction of part of population by the reaction of vigorous hosts.

For further biological details and control measures see Beeson, 1931, *Ind. For. Rec.*, XVI, ix, The life history and control of *Celosterna scabrator*, *F.*; also Part Two.

Ceresium flavipes in *Casuarina equisetifolia*.

Ceresium leucosticticum. *Acacia catechu*, *A. pennata*, *Albizzia lucida*, *A. odoratissima*, *Anogeissus latifolia*, *Careya arborea*, *Cassia fistula*, *C. siamea*, *Castanopsis argyrophylla*, *Dalbergia fusca*, *Dolichandrone stipulata*, *Grewia tiliæfolia*, *Lagerstroemia parviflora*, *Lannea grandis*, *Mallotus philippinensis*, *Scutia indica*, *Tectona grandis*, *Xylia dolabriformis*.

Beetle, C, 8–12 mm., brownish-black, with 9 white spots on elytra and 4 on prothorax, legs and antennae light brown. Emergence occurs in June to August with 55 percent in June.

Eggs are laid singly or in groups of two or three on the bark. The early larval galleries in some woods, for example in *Grewia tiliaefolia*, are constructed in the bark and bast, while in other woods, as for example *Anogeissus latifolia*, the galleries descend to the sapwood at once. They are shallow, tape-like and irregularly broadened due to repeated working over the same area. The pupal chamber enters abruptly from the sapwood surface, of the I-girder type about an inch long and lies in a longitudinal direction about half an inch below the surface; the cross-section of the prepupal neck is oval and plugged with clean coarse fibres. The generation is annual but emergences delayed up to three years in dry wood (e.g., of teak) have been recorded. Logs are attacked at the beginning of the rainy season following felling.

The egg and larva are described in 1927, *Ind. For. Rec.*, XIII, ii, p. 13, figs., 8, 33.

Ceresium nilgiriense in *Albizzia lebbek*, *Shorea robusta*. Emergence occurs in April, May, mainly in the latter. The generation of this sapwood borer is annual but emergences delayed up to five years in dry wood have been recorded. This species occurs with other secondary borers in dying poles of *Shorea robusta*.

Ceresium rotundicolle in *Berrya ammonilla*, *Cassia fistula*, *Dichopsis grandis*. The generation of this sapwood borer is annual.

Ceresium rufum in *Acrocarpus fraxinifolius*, *Castanopsis argyrophylla*, *Cassia fistula*, *Lagerstroemia flos-reginae*, *Pinus khasya*, *Pyrus communis*, and *Quercus serrata*, in Burma.

Ceresium zeylanicum in *Careya arborea*, *Heritiera fomes*, *Lagerstroemia parviflora*, *Shorea robusta*.

Chelidonium cinctum in *Citrus aurantium*, *C. medica*.

Beetle, C, 4/5ths to 1¼ inches, dark metallic blue-green, elytra with an irregular transverse yellow band. Eggs are laid in the axils of young living shoots of citrus trees and the larva bores into the centre of the shoot and works upwards for about an inch, and eventually cuts a complete spiral round it, then turns and bores downwards and enters the larger branches where it makes tunnels a quarter of an inch in diameter with ejection-holes at intervals. pupation occurs in a chamber closed at each end with a partition of chalk and fibres. The generation is annual and emergence occurs in May, June. It is a pest of orange and lime trees in South India. The bored shoots die and turn black.

LITERATURE:

K. Kunhikannan, 1928, *Dept. Agr., Mysore, Ent. Ser.*, Bull. 8 and *Ann. Rep. Dept. Agr., Mysore*. A Bulletin in Kanarese has been issued by the Coorg Government. The larva is described and figured by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, pp. 14, 15, pl. i, fig. 15, pl. ii, fig. 25.

Chelidonium sinicum in *Quercus lindleyana*.

Chloridolium alcmene in *Citrus aurantium*, *C. medica*.

Chlorophorus annularis in *Bambusa* sp., *Dendrocalamus strictus*, *Derris dalbergioides*, *Shorea robusta*, *Tectona grandis*.

Beetle, [fig. 4, No. 8], C, 8–15 mm., ochreous yellow with a dark brown or black pattern of curved and rounded spots on the elytra and pronotum. India to China and New Guinea.

This species is primarily a borer of dry bamboo. Emergence occurs in May–September, mainly in June. The generation is normally annual but the emergence of the beetle may take place at any time between May and September or may be delayed according to the dryness of the bamboo. In consequence development may continue after the bamboo has been made up into furniture, tent-poles, umbrella handles, chicks, etc., and the insect is frequently imported from the East to other countries.

The larva is described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, p. 47.

Chlorophorus anulifer in *Shorea robusta*. Emergence occurs in June–August, mainly in July. The generation of this sapwood borer is annual but emergences may be delayed up to two years.

Chlorophorus hederatus in *Albizzia odoratissima*, *Anogeissus acuminata*, *Hopea odorata*, *Pentacme suavis*, *Quercus griffithii*, *Q. serrata*, *Shorea robusta*.

Beetle, C, 10–12 mm., greenish-yellow with curved black bands. Emergence occurs in April–June mainly in May, but individuals have also emerged between August and January. The life-cycle of this sapwood borer is annual but in Assam and Bengal post-monsoon beetles apparently may lay eggs that produce beetles in the following May, and delayed emergence may occur as with other species of *Chlorophorus*.

Chlorophorus jucundus in *Acacia* sp., *Scutia indica*, and unidentified climber.

Chlorophorus 14-maculatus in *Lagerstroemia calyculata*, *Prunus avium* and *Xylia dolabriformis*.

Chlorophorus shoreae in *Shorea robusta*. May.

Chlorophorus strobilicola in *Pinus longifolia*. Beetle, C, 8–10 mm., purplish-brown to fuscous with the elytra black at the apices and two whitish transverse bands, the middle pair extending along the suture to the bases of the elytra.

Life-history: This species is a borer of the cones of *Pinus longifolia*. The beetles flight in April, May. Eggs are laid in June singly in the crevices between the scales of full sized green cones, about 15–20 on each cone. The larvae hatch in about two weeks and bore direct into the cone and feed on the internal woody tissue chiefly in the cellular parts of the scales and central axes avoiding the more strongly lignified vascular tracts. Several larvae may develop in one cone. A dozen is sufficient to stop the development of the cone, even before it has had time to assume the external appearance of a sound mature cone, so that it remains rather small and retains the glossy surface of the incompletely hardened stage. During the cold weather infested cones may fall to the ground; the scales do not separate as in the healthy ripe cone. Pupation takes place in the following April almost always in the broad scale heads, but sometimes in the central axis or other parts. The pupal period lasts about two weeks. Emergence is effected through oval holes in the scale-head. The life-cycle is normally annual with a pre-monsoon emergence-period in April and the first half of May.

Economic importance: The species attacks the cones of *Pinus longifolia* from altitudes of 2,000 feet (Dehra Dun) to 6,500 feet and is commonest in open sunny stands of chir pine. The damage done is almost negligible in a good seed year but when cones are few the proportion infested may rise to quite an appreciable figure, e.g. 40 percent.

Chreonoma frontalis in *Nauclea excelsa*, *Mitragyne diversifolia* in Burma.

Clytocera chionospila in *Acacia* sp., *Poinciania elata* *Pongamia glabra*, *Pterocarpus marsupium*.

Clytus balwanti in *Acacia pennata*, *Zizyphus oenoplia*.

Clytus ceylonicus in *Vitex altissima*. April–June.

Clytus minutus in *Strychnos nux-vomica*, *Tectona grandis*,

Vangueria spinosa.

Beetle, C, 5-7 mm., prothorax and legs reddish, elytra dark red to black with broad yellowish bands. [fig. 49, No. 3]. The larval galleries groove the sapwood and are filled with fine wood-dust. The entrance to the prepupal tunnel is oval and relatively large for the insect. The larval tunnels are illustrated in fig. 49, No. 3. Emergence occurs in March-May, mainly in March. The life-cycle is very variable and may be prolonged for over a year.

Clytus monticola in *Pistacia integerrima.* Beetle, 17 mm., dark brown, banded with yellow, on the wing in August. The larva is described in *Ind. For. Rec.*, XVI, iii, p. 173.

Clyzomedus transversefasciatus in *Ficus rumphii, Mangifera indica.*

Coloborhombus fulvus in *Zizyphus rugosa.* Beetle, C, 1¼ inches, yellowish-brown, vertex of head, prothorax and elytra with golden pubescence; the elytra are short and triangular and the hind wings are large and yellow and the beetle has a general resemblance to a large fossorial wasp. The larva is described in 1931, *Ind. For. Rec.*, XVI, iii, p. 199.

Coloborhombus hemipterus in *Eugenia* spp., *Psidium guava.* Beetle, C, 1 inch, black tinged with blue, vertex of head, prothorax and elytra with black pubescence. The beetle has the wasp-like form of *C. fulvus.* Recorded as boring in living guava trees, and, in Java, living clove trees. The life-cycle is annual in Java.

Coptops aedificator

Acacia arabica, Acrocarpus fraxinifolia, Aegle marmelos, Albizzia lebbek, Bauhinia purpurea, B. retusa, B. vahlii, B. variegata, Bombax malabaricum, Buchanania latifolia, Butea frondosa, Careya arborea, Cassia siamea, Coffee, *Cudrania javanensis, Dalbergia paniculata, Excaecaria agallocha, Ficus glomerata, F. religiosa, Ficus* sp., *Garuga pinnata, Hevea braziliensis, Holoptelea integrifolia, Lannea grandis, Manihot glaziovii, Millettia auriculata, Mucuna imbricata, Pavetta indica, Pongamia glabra, Pterocarpus marsupium, Pueraria tuberosa, Semecarpus anacardium, Shorea robusta, Spatholobus roxburghii, Terminalia belerica, T. tomentosa, Wrightia tinctoria.*

Beetle, L, 14-20 mm., brown, speckled with black and grey and some angular black markings on the elytra. [fig. 4, No. 4].

The beetle may be found on the wing throughout the year as emergence occurs in nearly every month, but the main emergence-period is May–August with approximately 17 percent in May, 32 percent in June, 19 percent in July and 11 percent in August. The life-cycle is normally annual. *Coptops aedificator* is a bark borer rather than a sapwood borer of dead trees. The later larval galleries and the pupal chamber are almost entirely in the bark, and the inner bast in contact with the sapwood is rarely broken. The dead outer bark is very thin near the final portions of the

larval gallery and pupal chamber. The early larval galleries graze the sapwood lightly. The exit-hole is circular and owing to the thinness of its edges is usually ragged. The larva is not distinguishable from that of *Coptops leucostictica*.

Coptops annulipes in *Pyrus communis*.

Coptops leucostictica in *Acrocarpus fraxinifolia*, *Albizzia lucida A. procera*, *Bauhinia vahlii*, *Lannea grandis*, *Shorea robusta*, *Terminalia myriocarpa*, *T. tomentosa*. Beetle, L, 14-27 mm., brownish or olivaceous, speckled with white and some black dots; antennal joints ringed with black. This species is a borer of thick bark. Emergence occurs between May and October, mainly in June. The life-cycle is annual sometimes prolonged to the second year. The larva is described in 1927, *Ind. For. Rec.*, XIII, ii, p. 56, figs. 50-53.

Coptops lichenea in *Ficus* sp., *Shorea robusta*, *Terminalia belerica*.

Coptops pascoei in *Ficus* spp., *Lannea grandis*.

Coptops variegata in *Pentacme suavis*.

Criocephalus tibetanus in *Cedrus deodara*, *Pinus excelsa*, *Pinus gerardiana*.

Beetle, C, ¾rs to 1¼ inches, dark brown, prothorax blackish [fig. 68, No. 3]. A borer of the sapwood and heartwood especially breeding in stumps. In Baluchistan it breeds in the trunk of dying trees of *Pinus gerardiana* in company with *Polygraphus trenchi* (Scolytidae); the exit-tunnel from the deeply seated pupal chamber is long and circular in cross-section. (See fig. 68 for illustration of the larval tunnel and pupal chamber). The life-cycle is annual with beetles in May. The larva and pupa are described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, pp. 36, 37, figs., 1, 2, 22, 31, 31 *a*.

Criocephalus unicolor in *Pinus khasya*.

Cycos subgemmatus in *Buchanania latifolia*, *Canarium euphyllum*, *Garuga pinnata*, *Terminalia myriocarpa*.

Beetle, L, 7/12ths to 1 1/8th of an inch, dark brown, thorax and elytra with black and orange markings, the apical fourth of the elytra with longitudinal orange streaks. There are two periods of emergence, May-July and November; beetles have been taken in September. The length of the life-cycle has not been determined but is at least six months. The larva is described in 1931, *Ind. For. Rec.*, XVI, iii, p. 183, fig. 31.

Cylindrepomus giraffa in *Ficus rumphii*.

Cylindrepomus signata in *Adina cordifolia*, *Ficus* sp.

Beetle, L, 12-15 mm., black with sharply outlined yellowish or white spots arranged in a scissors pattern on the elytra, scutellum also yellowish or white. [fig. 68, No. 6]. The emergence-period is May to August mainly in July. The generation is annual with occasional prolongation to the second year. See fig. 68, No. 6 for illustration of the pupal chamber, and imaginal tunnel from its lower end by which the beetle emerges.

Cylindrepomus uniformis in *Anogeissus latifolia.*

Cyriopalpus wallacei in *Pentacme suavis.* Beetle, C, 1½ to 2½ inches, reddish-brown, antennae spined in female and pectinate in male. The insect is a pest of green, healthy trees, apparently showing a predilection for timber of about 1′ 6″ to 3′ girth, and in large trees being therefore confined to the branches, hanging from which stalactites of solidified resin up to two feet long may be seen. The larva makes long ramifying tunnels 1½-3 inches in diameter running vertically up and down the trunk of the tree; the work of one individual can affect 2 or 3 feet of timber, and the work of 8 to 10 larvae is sufficient to make the timber of one tree useless for constructional purposes. It is not considered that the insect is a source of danger to the health of the tree or that it predisposes it to attack by the horde of secondary pests associated with *ingyin.* It is more probable that the general unthriftiness of the larger trees is due to over-maturity and lack of attention in the past, and that the insect attack and final death of the trees result from this rather than *vice versa.* Attacks by this insect may assume serious proportions when evenaged crops of *ingyin* are realised by the system of management. The larva is described by Gardner, 1931, *Ind. For. Rec.*, XVI, iii, p. 169, fig. 16, and the damage is figured by Garthwaite, 1940, *Guide to the borers of commercial timbers in Burma*, pl. iii, figs. 1, 2.

Demonax ascendens in *Shorea robusta*, dead twigs. Beetle, C, 5-7 mm., black with a light grey median band and a yellow inverted V. The life-cycle is annual.

Demonax atkinsoni in *Phyllanthus emblica*, *Quercus* sp., in Burma.

Demonax balyi in *Albizzia lebbek, Butea frondosa.* Beetle, C, 10-15 mm., orange-yellow elytra with black spots and brick-red prothorax. Emergence occurs in May. The life-cycle is annual with prolongation into the second and third years in dry wood; the delayed emergences also occur in May.

Demonax buteae in *Acacia catechu, Butea frondosa.*

Demonax formicoides in *Acacia gageana, Bauhinia vahlii* and other climbers.

Beetle, C, 6-8 mm., marked as in *Demonax ascendens* but with a grey patch on the apex of the elytra. Emergence takes place during the monsoon from the end of June to September, mainly in August.

Demonax limoniae in *Limonia acidissima.*

Demonax literatus in *Diospyros glandulosus, Phyllanthus emblica.* Emergence in April–June.

Demonax sonneratiae in *Sonneratia apetala.* Emergence in April, May.

Dere acaciae in *Acacia catechu.*

Dere cassiae in *Cassia fistula, Pithecolobium angulatum.* Emergence in April–June.

Derolus discicollis in *Acacia modesta, Heritiera fomes.* Beetle, C, 15–19 mm., black with a short brownish pubescence, disc of prothorax with a smooth rounded area. The larva after boring in the sapwood constructs a pupal chamber which is closed at its upper end with a plug of wood-dust that is lined on the inside with a hemi-ellipsoidal layer of calcium carbonate. The life-cycle is annual with beetles in June, July.

Derolus volvulus in *Acacia* sp., *Aegle marmelos, Albizzia lebbek, Bombax malabaricum, Bridelia retusa, Buchanania latifolia, Careya arborea, Garuga pinnata, Lannea grandis, Mallotus philippinensis, Pterocarpus marsupium, Shorea robusta, Xylia dolabriformis, Zizyphus xylopyrus.*

Beetle, C, 12–17 mm., dark brown. The larval tunnels of this borer lie mainly in the bark grooving the sapwood slightly; the total length of a tunnel is about 6 inches before it descends more deeply into the sapwood. It is either free of frass or filled very loosely. The pupal chamber is short and is closed by a hemi-ellipsoidal dome of calcium carbonate deposited on a plug of wood-dust; the calcareous lining is confined to the operculum; the walls of the chamber are bare as in *Aeolesthes.* The life-cycle is annual with emergence in April–August, mainly in May. The larva is described by Gardner, 1931, *Ind. For. Rec.*, XVI, iii, p. 168.

Desisa quadriplagiata in *Mallotus philippinensis.* Beetle, L, 9–12 mm. A borer of dry branchwood with an annual life-cycle emerging in May–July, (72 percent in June.)

Desisa subfasciata in *Anogeissus acuminata, Bauhinia vahlii, Mallotus philippinensis.* Beetle, L, 8–12 mm., brown mottled with black and a broad transverse white band on the elytra. A borer of small wood, dry climbers, etc. with an annual life-cycle emerging in May–October (24 percent in June, 36 percent in July). The pupal chamber has an upward extension near the junction of the prepupal tunnel; the beetle emerges from the prepupal tunnel.

Dialeges pauper in *Hopea odorata, Millettia auriculata, Parashorea stellata, Pentacme suavis, Shorea assamica, S. robusta.* A Malayan species not extending south of the Ganges. Beetle, C, 2/3rds to $1\frac{1}{4}$ inches, dark brown with a shining short pubescence having a longitudinally streaked gloss: antennae in male fringed with short hairs.

Life-history: Eggs are laid in cracks in the bark of newly felled or killed trees. The larval galleries groove the sapwood irregularly but not very deeply. The prepupal gallery runs into the heartwood for $\frac{1}{4}$ to $\frac{1}{2}$ an inch. The pupal chamber varies in orientation from almost horizontal or slightly curved downwards or vertically downwards; its length is one to two inches. The inside of the chamber is completely lined with calcium carbonate, spread on a very thin layer of fine wood-dust and extending in a band $\frac{1}{4}$ to 3/8ths of an inch beyond the point of attachment

of the operculum. The surface is somewhat roughly smoothed off with a dull finish; there is no internal film of sericinous or chitinous material as in *Diorthus cinereus*. The operculum is a thin fragile dome of calcium carbonate marked externally along the middle line by slight excrescences which sometimes expand into a flat-topped projection. The beetle escapes *via* the prepupal gallery and makes a subrectangular exit-hole in the bark.

D. pauper has two generations a year in Bengal and Assam; the overwintering generation emerges in April–July (April 55 percent, May 27 percent). Eggs laid in April, May produce second generation beetles in August–October (mainly October). In the eastern United Provinces the maximum emergence of the overwintering generation occurs in April but a portion of the population may not mature till July, August. The larva is described in 1926, *Ind. For. Rec.*, XII, ii, pp. 101–102.

Dialeges undulatus in *Berrya ammonilla*, *Prunus puddum*, *Pyrus communis*, *Xylia dolabriformis*.

Beetle, C, 16–20 mm. pitchy brown, elytra reddish-brown with patches of greyish pubescence resembling watered silk. Emergence occurs in April–June, mainly April. The life-cycle is annual with a portion of the generation taking two years.

Diastocera wallichi in *Albizzia odoratissima*, *Bombax malabaricum*. Beetle, L, 1 1/10th to 1 5/8ths inches, dull metallic bluish or bronzy green above and brilliant red below, the elytron with a round spot and two transverse bands of velvety black, the antenna with muffs of long silky black pubescence. The beetle feeds on young shoots of various woody plants gnawing the bark. The larval habits are not known.

Diboma alternata, L, in *Clerodendron* sp. in Madras.

Diboma biplagiata in *Strobilanthes* sp.

Diboma procera in *Acacia gageana*.

Dihammus admixtus in *Adina cordifolia*, *Anogeissus acuminata*, *Aporosa* sp., *Pterocarpus dalbergioides*, *Pterospermum acerifolium*.

Beetle, L, 12–15 mm. Andamans and Burma.

Dihammus andamanicus in *Canarium euphyllum*, *Terminalia procera*. Beetle, L, 1 inch. Emergence occurs in April, May.

Dihammus cervinus

Adina cordifolia, *Anthocephalus cadamba*, *Buddleia madagascarensis*, *Camellia thea*, *Clerodendron infortunatum*, *Gmelina arborea*, *Sarcocephalus cordatus*, *Tectona grandis*.

Beetle, L, 15–22 mm., uniformly light or greyish-brown, elytral length 8–19 mm. slightly longer in the female than in the male; beetles developing in teak are slightly larger than those in *Clerodendron*. [fig. 4, No. 11].

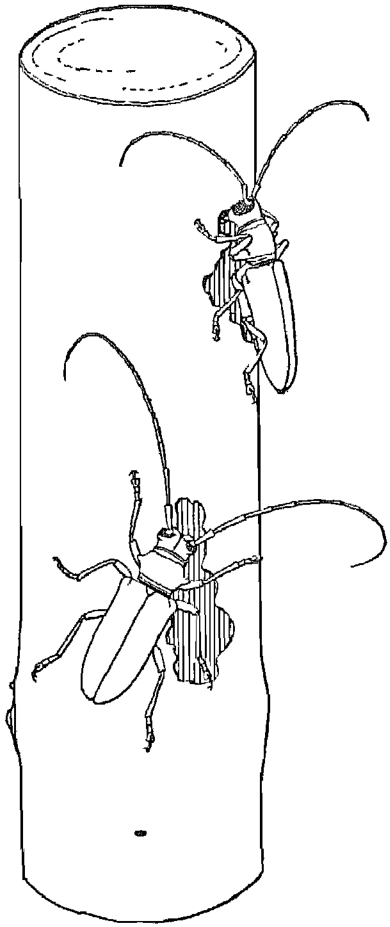


Fig. 50. Beetles of *Dihammus cervinus* gnawing patches in the bark of the stem of a living sapling of *Tectona grandis*. Natural size.

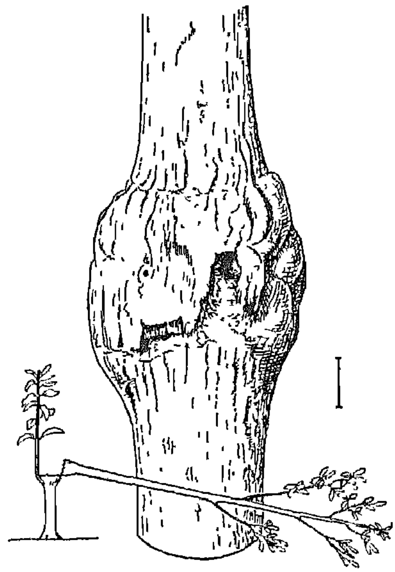


Fig. 51. Canker produced in the stem of a sapling of *Tectona grandis* by the attack of *Dihammus cervinus*, with exit-hole of beetle; vertical scale line represents one inch. Small figure shows a sapling broken off at the canker from which a subsequent coppice-shoot is growing.

Economic Importance.

This species, known as the canker-grub of teak, is an important pest of living trees in plantations of teak and *Gmelina arborea* in Northern India and Burma; it does not occur in the teak areas of the Indian Peninsula.

Partial girdling and injury to the cambium of teak induces an increased growth of wood around the wound. As a result of the

continued overgrowth in the callus a thickened bulging base or a globular canker sometimes twice the diameter of the stem is formed. [fig. 51] Most of the damage is done near ground-level but cankers are occasionally formed as high as 3 feet above ground. The healing of the canker is often delayed by the activities of termites and ants which may fill up the cavities with mud or assist the progress of wood-rotting fungi. In the case of extensive tunnelling by the larvae or of excavation by woodpeckers, the stem is so much weakened that it breaks off. Fig. 51 shows a teak sapling broken in two at the canker, with a coppice-shoot sprouting from the wound.

The attack on *Gmelina arborea* is different in effect. Possibly because the growth rate of *G. arborea* is relatively more rapid than that of teak, the tunnels of the larva in the region of the cambium are not so extensive and the formation of callus is less abundant. The larval tunnels are carried earlier into the heart of the sapling and tend to develop longitudinally in the wood. Consequently on *Gmelina* poles there is rarely more than a slight bulge as external evidence of the borer. Longitudinal and transverse fissures are formed but these heal more rapidly than in teak ; the base of the stem is distorted and thickened.

G. arborea may be attacked in its first year from seed; teak is usually too slender in its first year to be attacked. In the 2nd and 3rd years more than half of the growing-stock in a plantation may be attacked; in the 4th to 7th years the annual incidence falls off, and at the 7th or 8th year teak outgrows its liability to damage; *G. arborea* acquires immunity at an earlier age. The percentage of stems that break off at the canker may rise as high as 15 but is normally much less. Cankers are difficult to date and size is no indication of age. A cankered tree straightens out and absorbs the swelling by about the 10th year.

Life-history.

Food habits: The beetles feed mainly at night on the bark of the larval food-plants, gnawing irregular patches down to the wood which may sometimes girdle stems. Occasionally they eat leaf buds, and petioles and tender shoots. [fig. 50]. They shelter during the day in shady spots, under green leaves, etc. but not in the debris on the ground. They do not travel far and tend to remain in the vicinity of the larval breeding-grounds. Bait-traps effect a concentration of the beetle-population from a few hundred square yards. They are not attracted to light.

The commonest food-plant of *D. cervinus* is probably *Clerodendron infortunatum*; beetles bred in this food-plant do not show a preference for it against teak but lay eggs on either plant impartially. Because of its greater concentration and because of the lower mortality of *D. cervinus* in it, the presence of *C. infortunatum* in or near teak plantations very materially affects the

incidence of attack by *cervinus* on teak. So long as *Clerodendron* stems outnumber teak stems, the beetle-population is derived pre ponderantly from the weed. Later, as the *Clerodendron* is suppressed by the closing up of the canopy of the plantation, the incidence of attack increases relatively on teak. *D. cervinus* can also complete its development successfully in *Clerodendron* cut back in the hot weather. A ground fire which destroys all inflammable material above ground does not harm the larvae and pupae in *Clerodendron* roots an inch or so below ground-level.

Longevity: In the case of beetles (bred from *Clerodendron* and fed on *Clerodendron*) the average life in the laboratory was 27 days and the maximum life 70 days for a female and 57 days for a male. The last beetle died on 14th October. In outdoor cages the maximum life recorded for a pair was 119 days.

Oviposition: The beetles pair on the stems or branches of the host-plant as early as the first or second day after emergence and pairing is repeated during the oviposition-period at intervals of a few days. Oviposition begins on the third day of life of the female. A transverse incision is bitten deep into the bark, the tip of the ovipositor is inserted and an egg is pushed upwards between the inner face of the bark and the cambium layer. The incised hole is sealed with cement. The bark which is raised slightly over the site of the egg usually cracks longitudinally. Eggs are generally laid just above ground-level on *Clerodendron*, but often higher up the stem on teak and *Gmelina*.

The female has 20 ovarian tubes on each side and 4 eggs mature at a time. The maximum number of eggs laid by one individual is about 60; the average about 40. The maximum number of eggs laid by one female in one day is 7 and the average rate is 2 eggs per day. The longest oviposition-period recorded is 52 days; eggs were laid as late as 26 days after the last pairing. A female may live for two weeks after ceasing to lay.

Incubation period: The egg takes 5 days to hatch in May, and 5-7 days in August, the mode being 6 days.

Larval habits: On hatching the larva buries itself in the bast and by the end of a week has begun to eject fine fibres and particles through the bark-fissure. A tunnel is gradually excavated, irregular but trending downwards and round the stem. In 2 or 3 weeks the larva enters the sapwood. Tunnels made in the sapwood may reach a length of 10 inches at the end of 3 months, the larva then being about an inch long. The subsequent tunelling is in the wood (of the stem in teak and *Gmelina arborea* and in the root of *Clerodendron infortunatum*). A pupal chamber is constructed from May onwards; it is 1 to 2 inches long, clean of wood-dust, but closed by a plug of coarse fibres. The pupal period is 14 to 19 days; the beetle may bore out after 2 or 3 days or remain for a much longer period; the exit-tunnel is circular in cross-section and

is bored from the end of the pupal chamber opposite to that by which the larva entered. The following data show the proportions in which the larval, pupal and imaginal stages occur towards the end of the life-cycle in a typical infestation of *Clerodendron* in Haldwani, U.P. :—

Period ending	Larval stage percent	Pupal stage	Beetle in pupal cell	Beetle emerged
mid May ...	100	0	0	0
end May ...	74	23	3	0
mid June ...	50	6	44	0
end June ...	26	17	24	33
mid July ...	2	16	26	36

Emergence period: (*a*) The emergence from *Clerodendron* growing in the U.P. is June 15 percent, July 70 percent, August 15 percent. Emergence from *Clerodendron* in May and June was recorded at Pusa, Bihar. The emergence from *Clerodendron*, *Gmelina* and teak growing in Bengal and Assam is April 22 percent, May 72 percent, June 6 percent, i.e., two months earlier than in the U.P. In the Chittagong Hill Tracts, Bengal, pupae and immature beetles were in standing teak in the 2nd week of April, and emergence was recorded in Sylhet division, Assam in the first week of April.

(*b*) The emergence from teak growing in Sylhet division and caged at Dehra Dun on the 19th August, occurred in the following April and May. But emergence from *Clerodendron* collected in the same locality and caged on the same date as the teak occurred in August–October, mainly in September. In Sylhet, Mr. R.N. De bred out beetles from teak and *Clerodendron* collected in October. In the Chittagong Hill Tracts young larvae were detected in January in 7 months old *Gmelina arborea* (sown in the previous June) and full grown larvae in 11 months old *Gmelina arborea;* these larvae originated from eggs laid in the autumn when the plants were 4 or 5 months old.

Life-cycle: The life-cycle of *D. cervinus* indigenous in the western United Provinces is annual. Beetles imported from Sylhet, Assam, to Dehra Dun also produced a generation in Dehra Dun that occupied a full year. The progeny of Assam parents reared on *Clerodendron* and teak in the laboratory developed as follows :—Egg stage 5 days, larval stage 320 days, pupal stage 17 days, immature beetle stage about 23 days; May to May. In eastern Bengal and Assam there are two generations a year, the first starting in April–June, and the second in August–October but it is probable that the latest broods of the first generation do not mature after the monsoon but are prolonged until the following hot weather. The life-cycle in Burma is probably also double with prolongation of late first generation broods to the following hot weather. For control measures see Part Two.

LITERATURE :

The egg, larval stages and pupa are described by Gardner, 1927, *Ind. For. Rec*, XIII, II, pp 50–52, figs. 37–40, 44.

Beeson, 1925, *Ind. For.*, LI, pp. 187–192, pl. 13, figs. 1–17. The teak canker-grub

Atkinson, 1931, *Burma For. Bull.*, No. 26, pp. 8, 9, pl. IX, Insect damage to the timber of teak.

Beeson and Bhatia, 1939, *Ind. For. Rec.*, Ent., V, No. 1, pp. 59-66, Biology of the Cerambycidae

Dihammus elongatus in *Acrocarpus fraxinifolius, Aesculus punduana, Anthocephalus cadamba, Casearia glomerata, Clerodendron* sp., *Duabanga sonneratioides, Echinocarpus dasycarpus, Gmelina arborea, Juglans regia, Litsaea kingii, Macaranga denticulata, Mallotus roxburghianus, Michelia excelsa, Ostodes paniculata, Sapium eugeniaefolium, Tectona grandis, Terminalia myriocarpa.*

Beetle, L, 14 mm., uniformly light or greyish-brown, resembling *D. cervinus*. Bengal to Burma. The life-cycle is annual with emergence in April–July (April 32 percent, May 44 percent and June 18 percent). This species is a borer of dead and felled wood.

Dihammus gardneri in *Anogeissus acuminata*, and *Tectona grandis* in Burma.

Dihammus griseipennis in *Strobilanthes acrocephalus*. Bengal to Burma.

Dihammus griseoplagiatus in *Adina cordifolia, Bombax malabaricum, Ficus tsiela, Garuga pinnata, Holigarna arnottiana, Hopea wightiana, Lannea grandis, Mangifera indica, Pterospermum heyneanum, Spondias mangifera, Terminalia belerica, T. paniculata, T. tomentosa, Vateria indica.* Indian Peninsula.

Beetle, 17–20 mm., dark brown with patches of greyish-white pubescence on the elytra [fig. 69, No. 2]. The life-cycle is annual with emergence in May–August (May 23 percent, June 55 percent, July 20 percent). The larval tunnel and pupal chamber are illustrated in fig. 69, No. 2. Emergence occurs through an imaginal tunnel from the base of the chamber.

Dihammus inaequalis in *Alnus nepalensis, Evodia fraxinifolia, Juglans regia, Macaranga denticulata.*

Beetle, L, 12–16 mm., uniformly dark greyish-brown, elytral surface irregular. Bengal to Burma. The life-cycle is annual with emergence in February–May (March 80 percent, April 11 percent).

Dihammus longiscapus in *Ficus tsiela, Holigarna arnottiana, Lannea grandis.*

Dihammus punctifrons in *Aesculus punduana, Cajanus indicus, Duabanga sonneratioides, Ficus elastica, Garcinia paniculata, Garuga pinnata, Homalium tomentosum, Tectona grandis, Terminalia belerica, T. myriocarpa.* Beetle, L, 13–18 mm., greyish-brown, with black punctures on the front of the head. Burma to the United Provinces. The emergence-period

from felled timber is April–July, mainly May and the life-cycle is apparently annual. It is recorded as breeding in transplants (root and branch-pruned) of *Ficus elastica*, put out in March in Assam, and causing their death. It has also been found breeding in living *Cajanus indicus* stems.

Dihammus rusticator in *Afzelia bijuga, Artocarpus integrifolia, Excaecaria agallocha, Ficus elastica, Hevea braziliensis, Ricinus communis, Theobroma cacao.* Beetle, L, 1 inch, light brown with greyish shades. Widely distributed.

The life-cycle in dead wood is annual, with emergence in April, May. It is recorded as attacking living cocoa trees. The larva lives between the outer bark and cambium and its galleries often completely girdle the tree but not always fatally.

Dihammus sericeus in *Terminalia myriocarpa.* Beetle, L, 10–13 mm.

Diorthus cinereus.

Acacia leucophloea, Albizzia odoratissima, Anogeissus latifolia, Bauhinia vahlii, Butea superba, Cassia fistula, Dalbergia fusca, Dichopsis grandis, Eugenia sp., *Hardwickia binata, Heritiera fomes, Lannea grandis, Mallotus philippinensis, Scutia indica, Shorea robusta.*

Beetle, C, ⅔rds to 1¼ inches, dark brown with a close greyish pubescence and an intricately wrinkled pronotum. Africa to Java.

Life-history: Felled and fallen trees are attacked within a few months of death and eggs are laid in crevices in the bark. It also breeds in the dead crowns of stagheaded trees and the trunks of trees dying from drought or other causes. The woody lianes of *Bauhinia vahlii* cut in creeper-cleaning operations are abundantly attacked and the crowded larval galleries reduce the interior to a mass of loose fibres and dust. In timber logs the larval galleries in the sapwood groove it fairly deeply and are packed with rather finely comminuted wood and bark-dust. The prepupal tunnel leaves the sapwood and enters the heartwood in a full curve and terminates in a short vertical pupal chamber which is about half as long as the prepupal tunnel. The latter is usually cleared of excavated material which is in the form of fine dust and very short fibres and is packed away in the larval galleries in the bark. A small plug of wood-fibres is retained to close the mouth of the pupal chamber and against it is rammed a wad of finer dust arranged to form a hemispherical depression which corresponds in concavity to the opposite termination of the pupal chamber. The larva lines the whole of the chamber thus formed with a thin layer of calcium carbonate and finally glazes the inner surface with a film of non-elastic material of sericinous or chitinous nature, which varies in colour from fawn to deep chestnut brown. The operculum of *D. cinereus* is thus a simple hemispherical or hemielliptical cap continuous with the lining of the pupal chamber.

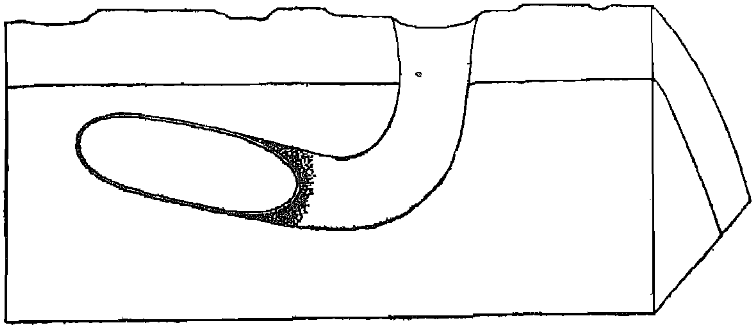


Fig. 52. Pupal chamber of *Diorthus cinereus* in longitudinal section with calcareous operculum intact against a wad of wood-dust. The boundary between sapwood and heartwood is indicated; bark is missing; the eroded surface of the sapwood, at the top, shows the depth of the larval galleries. Natural size.

The beetle breaks through this partition in order to escape [fig. 52].

The life-cycle is annual with a premonsoon emergence-period in April–July, May 34 percent, June 42 percent. Under unfavourable conditions emergence may be delayed until July or until June of the second year. The larva is described by Gardner, 1926, *Ind. For. Rec.*, XII, ii, pp. 100, 101.

Diorthus sericeus in *Acacia* sp., *Pterocarpus marsupium*.

Distenia dravidiana in *Holigarna arnottiana*, *Mangifera indica*. Beetle, C, 17–20 mm., head, prothorax and underside dusty metallic blue, elytra light brown tinged in places with blue, legs yellow. May, June. The larva is described in 1931, *Ind. For. Rec.*, XVI, iii, pp. 165, 166.

Enispia cleroides in *Evodia fraxinifolia*. Beetle, L, 8–15 mm.

Enispia ochraceovittata in *Ficus* sp. Beetle, L, 10 mm.

Entetraommatus quercicola in *Quercus incana*.

Epania amoorae in *Mimusops elengi*.

Epania calophylli in *Calophyllum wightianum*. Beetle, C, 7 mm., head and prothorax reddish-brown, elytra short, squarish, brownish-yellow. Emergence occurs in March; the life-cycle is annual. The larval tunnels are shallow just grooving the sapwood; the pupal chamber is long with dust-filled expansions at each end, and traces of a white shining film.

Epania cingalensis in *Diospyros ovalifolia* in Ceylon.

Epepeotes andamanicus in *Canarium euphyllum*, *Macaranga* sp. Beetle, L, 5/6ths to 1 inch, greyish on dark brown ground, with 3 greyish streaks on the prothorax. Emergence in May. The larva is described in 1931, *Ind. For. Rec.*, XVI, iii, pp. 182, 183.

Epepeotes gardneri in *Lannea grandis*.

Epepeotes guttatus in *Ficus foveolata*. Beetle, L, ⅞rs. to 1 1/16ths of an inch, black with white spots on the elytra and white lines on the head and pronotum. Emergence in May. The larva is described in 1931, *tit. cit.*, XVI, iii, p. 183.

Epepeotes luscus in *Artocarpus integrifolia, Castilloa elastica, Ficus elastica, F. hispida, Mangifera indica, Theobroma cacao.* Beetle, L, 7/10ths to 1 1/10th of an inch, reddish-brown with vague grey markings and two black shoulder spots on the elytra. Emergence in Burma occurs in May. In Java there are 3 generations a year, the shortest life-cycle being completed in 2½ to 3 months with prolongation upto 10 months, the beetles emerging in the rainy seasons mainly in October, November and in January, February and in June, July but also in all months except the driest. The female lives for over 4 months and may lay upto 1,400 eggs, often 400 eggs in one month.

Epepeotes uncinatus in *Crataeva unilocularis, Ficus carica, F. elastica, F. religiosa, Morus indica, M. laevigata, Terminalia myriocarpa.*

Beetle, L, 2/3rds to 1 1/10th of an inch, thorax and head black with white lines, elytra greyish with irregular black spots. Emergence occurs in April–June, mainly May. The life-cycle is annual. The prepupal tunnel and pupal chamber are carried deeply into the wood. The beetle escapes by an imaginal tunnel from the base of the pupal chamber. The variety *salvazai* Pic bores *Artocarpus integrifolia.*

Epipedocera acaciae in *Acacia arabica.*

Epipedocera affinis in *Grewia tiliaefolia, Lagerstroemia parviflora, Woodfordia floribunda.* Beetle, C, 7 to 12 mm., black with a yellow enamelled spot in the middle of each elytron, legs black. Emergence occurs in June–September, mainly June. The life-cycle of this sapwood borer is annual. The larva is described in 1927, *Ind. For. Rec.*, XIII, ii, pp. 47, 48.

Epipedocera assamensis in *Quercus serrata.*

Epipedocera chakhata in *Bauhinia vahlii.*

Epipedocera parva in *Bauhinia vahlii, Lagerstroemia parviflora.*

Epipedocera zona in *Grewia tiliaefolia, Shorea robusta, Terminalia tomentosa.* The life-cycle of this sapwood borer is annual with emergence in June–August, mainly July: under unfavourable conditions the life-cycle is prolonged two or three years.

Eunidia apicemaculata in *Albizzia stipulata.* Beetle L, 8 mm.

Eunidia lateralis in *Acacia* sp. in south India,

Eunidia simplex in *Acacia gageana, Albizzia lucida, Terminalia myriocarpa.*

Eupogoniodes carissae in *Carissa spinarum, Cryptolepis buchanani, Holarrhena antidysenterica.* L, 8-11 mm., testaceous

or light brown with greyish speckling. This species bores dry stems of climbers and twigs, mining in the pith for several inches and emerges in February-May. The larva has a pair of small separated spines on the 9th abdominal tergite; see 1930, *Ind. For. Rec.*, XIV, xiii, p. 286.

Eupogoniodes gardneri in *Cryptolepis buchanani*. 6-8 mm. The beetle emerges in April-August, April 30 percent, May 44 percent. The larva has a pair of large approximate spines on the 9th abdominal tergite, and is described *tit. cit.*, p. 285.

Euryphagus lundi in *Dipterocarpus alatus, Shorea robusta.* C, 13-25 mm.

Exocentrus albizziae in *Acrocarpus fraxinifolius, Albizzia lebbek.*

Exocentrus alboguttatus in *Acacia arabica, A. gageana, Anogeissus latifolia, Bauhinia vahlii, Clerodendron infortunatum, Cudrania javanensis, Flemingia semialata, Grewia oppositifolia, Lannea grandis, Mallotus philippinensis, Millettia auriculata, Morus alba, Ougeinia dalbergioides, Pavetta indica.*

Beetle, L, 6-8 mm., head black, prothorax and elytra dark brown. A borer of dry branchwood, stems and climbers. The life-cycle is annual with prolongation into the 2nd and 3rd years. Emergence occurs in May-October, 14 percent in May, 25 percent in June, 39 percent in July, 12 percent in August.

Exocentrus alni in *Alnus nepalensis, Evodia fraxinifolia.*

Exocentrus beesoni in *Cassia siamea* in Madras.

Exocentrus carissae in *Carissa opaca, Flemingia stricta, Girardinia heterophylla, Mallotus philippinensis.*

Exocentrus cudraniae in *Acacia gageana, Carissa opaca, Combretum decandrum, Cudrania javanensis, Engelhardtia colebrookiana, Ficus clavata, F. glomerata, Flemingia stricta, Indigofera tinctoria, Lannea grandis, Mallotus philippinensis, Millettia auriculata, Ougeinia dalbergioides.* Beetle, L, 3-5 mm., brownish, basal half of elytra irregularly marked with white and a white transverse stripe in the apical quarter. The life-cycle is annual with prolongation to the second year; emergence occurs in May-August, mainly in July.

Exocentrus dalbergiae in *Acacia gageana, Bauhinia vahlii, Clerodendron infortunatum, Dalbergia sissoo, Engelhardtia colebrookiana, Euphorbia pulcherrima, Flemingia stricta, Lannea grandis, Mallotus philippinensis, Millettia auriculata, Ougeinia dalbergioides, Pterocarpus marsupium.* Beetle, L, 3-7 mm., uniformly brownish with dense long black hairs on elytra, and 3 whitish stripes. North and central India. A borer of dry twigs, stems and climbers; the life-cycle is annual with prolongation to the second year. Emergence occurs in June-December. June 16 percent, July 31 percent, August 13 percent, September 27 percent.

Exocentrus ficicola in *Ficus hispida, Mangifera indica, Thespesia populnea.*

Exocentrus flemingiae in *Acacia gageana, Flemingia stricta.*

Exocentrus grewiae in *Grewia oppositifolia, G. vestita, Milletia auriculata.*

Exocentrus malloti in *Mallotus albus.*

Exocentrus parrotiae in *Juglans regia, Parrotia jacquemontiana.*

Exocentrus pubescens in *Albizzia lebbek.*

Exocentrus terminaliae in *Terminalia belerica.*

Falsomesosella andamanica in *Hopea wightiana*, L, 10 mm.

Falsomesosella bifasciata in *Acacia leucophlaea.*

Falsomesosella gardneri in *Bauhinia vahlii, Mallotus philippinensis.*

Falsomesosella tranversefasciata in *Butea frondosa.*

Gelonaetha hirta in *Anogeissus latifolia, Berrya ammonilla, Dipterocarpus* sp., *Grewia* sp., *Heritiera fomes, Tectona grandis.*

Beetle, C, 8-20 mm., reddish to dark brown sparsely clothed with grey pubescence and long tawny hairs. Oriental and Australian Regions. This species makes shallow, rambling, interlacing galleries packed closely with fine wood and bark dust and covering the whole surface of the sapwood (often the most conspicuous surface work on girdled teak trees). It pupates at a depth of an inch or less in a chamber of the **I** girder type, i.e., with a transverse slit across the top and the bottom ends, which are closed with fibres. The life-cycle recurs twice in twelve months with two emergence-periods, premonsoon in March–June (April 37 percent, May 26 percent.) and post-monsoon in September–December (October 43 percent, November 39 percent), with facultative prolongation of the normal biannual cycle from a minimum of four and a half months (May–September) to one, or one and a half or two years. The delayed development is mainly due to the drying out of the wood containing the larval tunnels.

LITERATURE :

Atkinson, 1931, *Burma For. Bull.*, No. 26, p. 12, pl. xii (illustration of damage to teak).

Gardner, 1927, *Ind. For. Rec.*, XIII, ii, p. 42, i, fig. 6, pl. ii, fig. 19, (larva).

Beeson and Bhatia, 1939, *Ind. For. Rec.*, Ent., v, No. 1, pp. 80, 81.

Glenea arithmetica in *Calophyllum walkeri*, L, 15 mm.

Glenea beesoni in *Juglans regia.* Beetle, L, 12 mm., yellow with black contiguous streaks and spots. Emergence occurs in June. The larva and pupa are described by Gardner, *Ind. For. Rec.*, XIII, ii, pp. 59, 60, figs. 54-56.

Glenea belli in *Artocarpus integrifolia.*

Glenea cancellata in *Mallotus philippinensis.*

Glenea decorata in *Heritiera fomes.*

Glenea galathea in *Gmelina arborea, Tectona grandis.*

Glenea homonospila in *Bombax malabaricum, Sterculia alata.* Beetle, L, 15 mm., yellow, with black bands and spots, antennae black. Emergence occurs in April–July, mainly June.

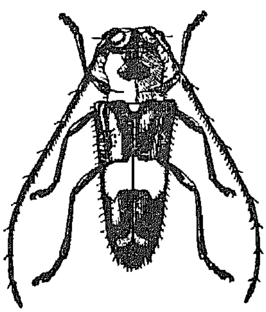


Fig. 53. Beetle of *Glenea indiana*, twice natural size (15 mm.)

Glenea indiana in *Bucklandia populnea, Gmelina arborea, Tectona grandis.*

Beetle, L, 12-15 mm., black, elytra with a median transverse yellowish band and two apical spots, scutellum yellow, prothorax with yellow collar [fig. 53]. Burma to Western U.P.

The life-cycle is annual with emergence in May–July, mainly May. This sapwood borer breeds in dying saplings and in stumps as well as in felled trees. The pupal chamber is comma-shaped just below and parallel to the surface of the sapwood, 1 to 1½ inches long; the beetle emerges *via* the larval entrance tunnel; the exit-hole in the bark is circular. The tunnel in teak wood may simulate a small failed beehole. The larva and pupa are described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, p. 60. The damage done is illustrated by Atkinson, 1931, *Burma For. Bull.*, No. 26, p. 10, pl. x.

Glenea jacintha in *Pterospermum acerifolium.*

Glenea lecta in *Magnolia pterocarpa, Phoebe lanceolata.*

Beetle, L, 12 mm., black with white spots and markings. [fig. 61, No. 1]. Emergence occurs in April, May, mainly April. The location and shape of the pupal chamber and exit-hole are illustrated in 61, No. 1.

Glenea multiguttata in *Bombax malabaricum, Boswellia serrata, Buchanania latifolia, Garuga pinnata, Holigarna arnottiana, Lannea grandis, Mangifera indica, Pterocarpus marsupium, Shorea robusta.*

Beetle, L, 8–15 mm., head and prothorax yellow with black spots, elytra orange to greyish-brown, spotted with black, apex yellow. [fig. 4, No. 3]. This sapwood borer has an annual life-cycle with emergence in April–June, mainly May. The pupal chamber is at right angles to the prepupal tunnel and the beetle escapes from its upper end. The larva is described in 1931, *Ind. For. Rec.*, XVI, iii, pp. 195, 196.

Glenea nigrolineata in *Kydia calycina.* Beetle, L, 17 mm., yellowish-brown with black markings. The larva is described in 1931, *tit. cit.*, p. 195, fig. 36.

Glenea ornata in *Castanopsis* sp.

Glenea pulchra in *Sterculia alata.*

Glenea 14-maculata in *Abies webbiana, Pinus excelsa, P. gerardiana, P. longifolia.*

Beetle, L, 12 mm., yellow with 4 black spots in a row on each elytron and 6 on the prothorax. A sapwood borer of the large and small branches and trunks of conifers. The larval galleries groove the sapwood fairly deeply and when almost fully developed

occupy the whole thickness of the bark of small branches so that a thin pellicule of outside bark is left; this frequently tears under the strain and exposes the gallery. The gallery is packed tightly with long wood-fibres and very little dust. The exit-hole is circular and communicates with the prepupal tunnel. The life-cycle is annual with emergence in March-August mainly April at 2,000′; it is on the wing from April onwards at higher elevations. The larva and pupa are described in 1927, *Ind. For. Rec.*, XIII, ii, pp. 58, 59.

Glenea sanctae-mariae in *Vatica lanceaefolia.*

Glenea silhetica in *Terminalia myriocarpa.*

Glenea spilota in *Bombax malabaricum, Sterculia villosa.* Beetle, 12–24 mm., yellow, with 7 to 9 black spots on each elytron, and 6 on prothorax, antennae black, legs orange. North India and Malaya. This species is the commonest of the *Gleneas* attacking *Bombax malabaricum*; it breeds in the sapwood of the felled trunk and branches and also in dying saplings and poles. The life-cycle is annual with emergence in April–July (April 16 percent, May 68 percent, June 15 percent). Fig. 54 shows a graph of the emergence-period. The egg and larva are described in 1931, *tit. cit.*, p. 195, figs. 37, 38.

Glenea vaga in *Grewia vestita, Kydia calycina, Lannea grandis.* Beetle, L, 11 mm., brown with greyish-white spots and markings, occurs in March–October. The larva is described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, p. 59 as *Glenea* (*Stiroglenea*) sp.

Gnatholea simplex in *Albizzia odoratissima, Hardwickia binata, Millettia pendula, Pongamia glabra, Shorea robusta.*

Beetle, C, 12–24 mm., vandyke brown, rather densely covered with drab-grey pubescence; the mandibles of the male project forwards. The life-cycle of this sapwood borer is annual with prolongation under dry conditions upto three years; emergence takes place in May–August, mainly in May. The larva is described and figured in 1927, *tit. cit.*, p. 41, fig. 11.

Golsinda basicornis in *Bauhinia vahlii.*

Hoplocerambyx spinicornis.

Duabanga sonneratioides, Hevea braziliensis, Parashorea robusta, Pentacme suavis, Shorea assamica, S. obtusa, S. robusta.

The range of this species is from the Philippines and Borneo to the extreme western and southern limits of forests of *Shorea robusta* in India. It does not extend into dipterocarp forests in south India. It appears to be absent from intensively worked sal forests in the Gangetic plain (e.g., Gorakhpur, United Provinces) owing to the dearth of breeding-material.

Beetle, C, 4/5ths to 2½ inches, uniformly very dark brown, the elytra varying in colour from piceous black to reddish-brown; antennal segments with spines at corners. [fig. 4, No. 1, male]. The egg, larva and pupa are described and figured by Gardner,

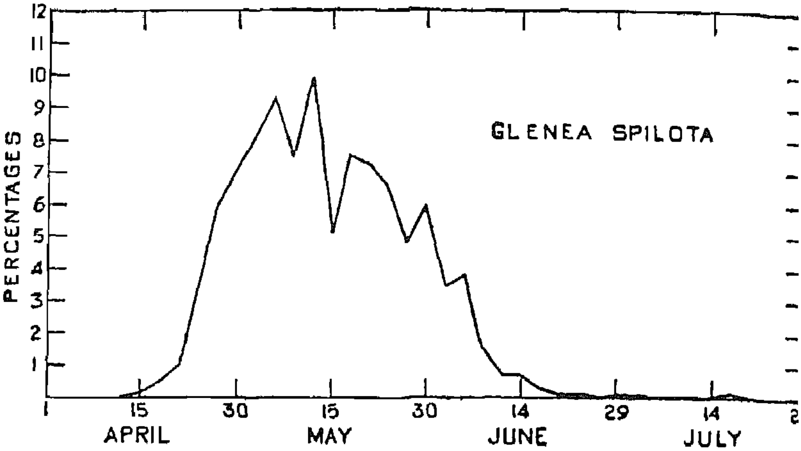


Fig. 54. Graph of emergence of *Glenea spilota* from *Bombax malabaricum* showing percentages of the total annual population of beetles emerging at 3-day intervals.

1925, *Ind. For. Rec.*, XII, ii, pp. 92–96, pl. i, figs. 1-7, 9, 11, pl. ii, figs. 13, 16, 17, 20, 25-27, 29, 30.

Aeolesthes holosericea may easily be confused with *Hoplocerambyx spinicornis* in all its stages. The two species can be distinguished as follows:—

LARVA. Head without a distinct genal carina. Dorsal ampullae on abdomen with separate rounded tubercles in four transverse lines..**Hoplocerambyx.**

Head with a distinct genal carina. Dorsal ampullae on abdomen with tubercles larger and less well defined..........**Aeolesthes.**

CALCAREOUS OPERCULUM. Helmet-shaped and externally convex with a ridge. No beading [fig. 42, No. 8] **Hoplocerambyx.**

Gandhi-cap-shaped and externally concave with no ridge. Beading on wall of chamber [fig. 42, No. 9].............**Aeolesthes.**

BEETLE. Antennal segments with spines [fig. 4, No. 1] ....**Hoplocerambyx.**

Antennal segments without spines at corners [fig. 4, No. 10] ....**Aeolesthes.**

Life-history and Economic Status.

The life-history of *Hoplocerambyx spinicornis* has been described generally and illustrations of the insect and the damage done are available in several previous publications. Reference may be made to Beeson and Chatterjee (1924), Atkinson (1926), Muir (1929), and other papers in the list of Literature at the end of the account of this species. The economic importance and control of this species has also been recorded in several papers.

The following simplified story of the life-history may be found useful for the information of subordinate staff and for translation into local languages.

*   *   *   *   *

LIFE HISTORY OF THE SAL BORER

[see fig. 42, No. 7, 8]

The beetles of the sal borer, *Hoplocerambyx spinicornis*, begin to appear each year as soon as the monsoon rains start. If several inches of rain falls early in June the beetles appear a few days afterwards; if the monsoon does not start until July no beetles will be seen until after the rain has fallen. They do not all emerge at once; each rainstorm brings out a fresh lot of beetles and this goes on for about eight weeks when probably 95 percent of the total will have emerged. 35 inches of rain after June 1st is sufficient to cause a total emergence. A beetle lives for about three or four weeks, so some of the earliest will have died before the latest have emerged.

They pair at once and lay eggs on the bark of sal trees. The trees that are chosen are dead or practically dead, i.e., felled trees, windfalls, trees washed out by floods, or struck by lightning, or broken by storms or damaged in felling-areas, or attacked by root-fungus. Healthy standing trees are not attacked unless there is an epidemic of the borers and the beetles are so numerous that the dead trees are insufficient for them. Each beetle will lay 100 to 300 eggs. The eggs do not all survive to beetles; a big sal tree will rarely produce more than 300 beetles although early in the attack there may have been a thousand grubs in its bark. The grubs that hatch from the eggs feed under the bark, and then in the sapwood, and finally bore into the heartwood. One can tell how far the attack has progressed by examining the dust thrown out of holes in the bark, which falls to the ground at the base of the tree and accumulates in a heap often 2 or 3 feet deep. If there is a good deal of heartwood dust it means that the grubs are nearly full grown. Ordinarily the grubs have entered the heartwood and become full grown by November. During the winter and hot weather they stay in tunnels in the heartwood shut in by a partition of white lime (calcium carbonate) and long wood-fibres closely packed. [fig. 42] The insect turns into a beetle in May–June and waits until the monsoon arrives.

The beetle and the grub of *H. spinicornis* look very much like the beetle and grub of another sal borer, *Aeolesthes holosericea*, and as they are difficult to distinguish it is best to send specimens to the Forest Research Institute to have them named. The beetles of *A. holosericea* are found in sal wood in the cold weather and they fly in March–May, which fact often makes people think that *H. spinicornis* flies at two periods in the year.

H. spinicornis is normally a species breeding in felled and dying trees and 25 years ago was not considered a particularly

destructive pest of standing living trees. Nowadays it ranks as the potentially most injurious forest insect in India. This is partly due to a series of bad epidemics in the United Provinces and in Central India, and partly to a better realisation of the financial importance of such catastrophes as well as of its more diffuse endemic activities. The average annual loss due to the sal borer in Government forests is not less than two and a half lakhs of rupees, or about 2 annas per acre per annum; in epidemics the loss may rise to enormous proportions. In a small epidemic affecting 8 square miles of forest in the United Provinces 45,000 trees amounting to nearly a million cubic feet of timber were killed, representing a loss of Rs. 2,70,000 or Rs. 18 per acre. The most serious epidemic on record affected five forest divisions of the Central Provinces, an Indian State and much private land. When remedial measures were started it was found that on 150,000 acres of sal forest in two divisions, timber to the extent of Rs. 7,50,000 had been destroyed. In the following year the attack had risen to five and a half million trees on this area representing a loss of forest capital in the neighbourhood of Rs. 1,37,50,000. The total number of trees attacked over the whole infested area before the epidemic was checked is estimated at about seven million. Four years of control operations and an expenditure of Rs. 1,25,800 were required before the epidemic was definitely overcome.

The control measures for *H. spinicornis* are probably now the most effective and best organised of any devised for Indian forest protection and outbreaks serious enough to require departure from the working-plan prescriptions have been very rare in recent years. The measures that can be used vary according to the extent of the outbreak, the type of sal forest and the conditions of management. For details the prescriptions in Part Two must be consulted.

* * * * *

THE ECOLOGICAL AND PHYSIOLOGICAL STUDIES OF THE BORER ON WHICH THE CONTROL MEASURES ARE BASED.

Habits of the adult.

Hoplocerambyx spinicornis beetles are active by daylight and particularly during the warmest part of the day, 1 to 5 or 6 p.m. They avoid direct sunshine by sheltering in shady places, but when the sky is overcast and if a drizzle or moderately heavy rain is falling they readily take flight and may cover long distances in the open. In jungle the flight is low as well as slow and frequently interrupted by halts on trees or bushes accidentally encountered

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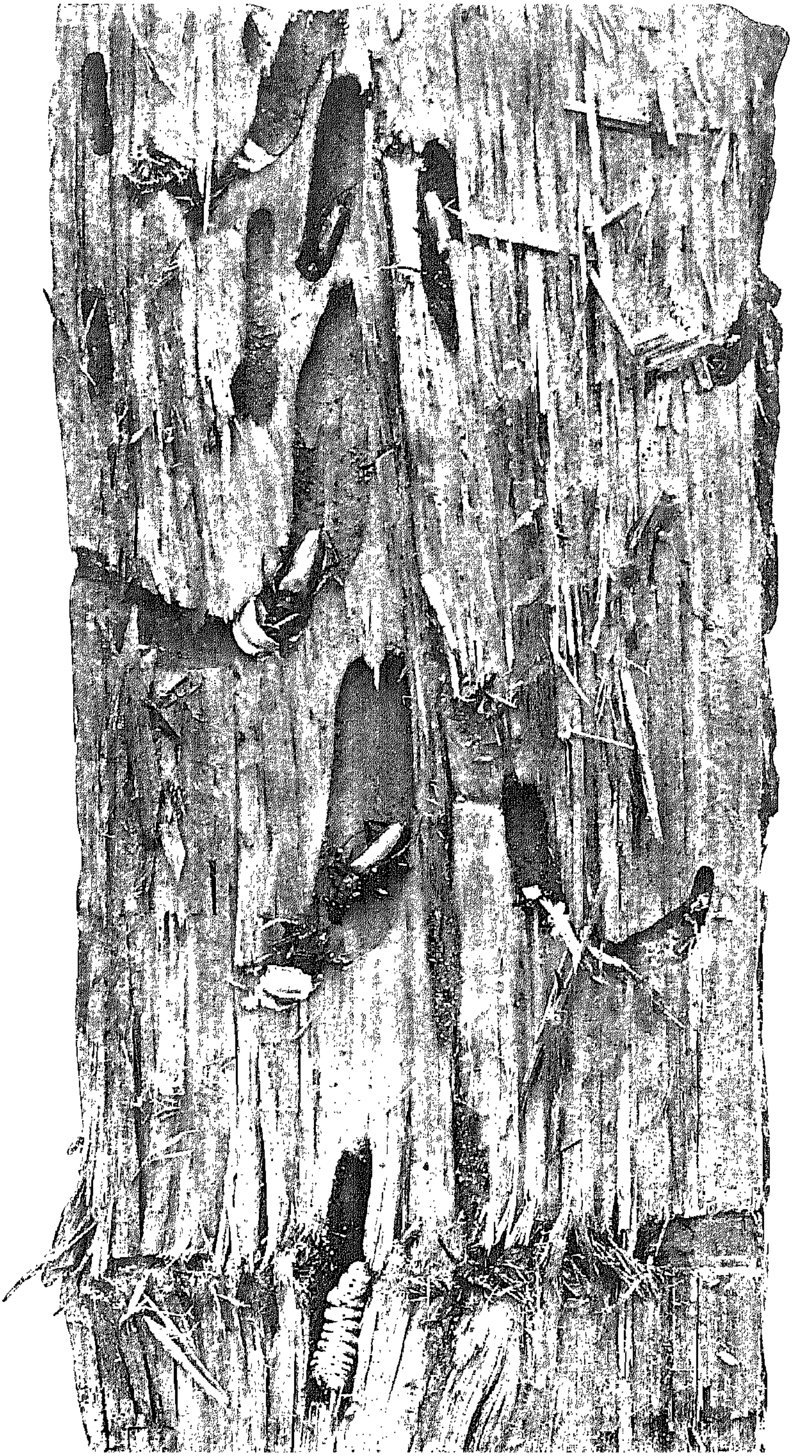
Fig. 55. The sal borer, Hoplocerambyx spinicornis.

Log of *Shorea robusta* from which the bark and much of the frass have been removed to show the larval tunnels of *Hoplocerambyx spinicornis* in the sapwood; 3 larvae are seen in place; at the top of the log is an entrance-hole to the prepupal tunnel.



but the general direction is well controlled. They run actively over the bark of trees and often assemble in large numbers on a particular tree for mating. Ordinarily at sunset they retire to sheltered spots such as the undersurface of logs, crevices and flakes of bark, large leaves, etc., where they rest with the underside of the body pressed close to the surface of the shelter. But they are readily active after dark if stimulated, and have been attracted to trees felled as late as 10 p.m.

Food: For food they gnaw the bark of sal, particularly the inner and living bark, when it is exposed by some accident to the tree. Fresh sap from the bast and sapwood of *Shorea robusta* is highly attractive and is imbibed with avidity until the alimentary canal is fully distended. A beetle that is gorged on sap appears intoxicated and often is unable to stand or fly. Fresh sap can be detected by the beetle from considerable distances; beetles have been attracted to newly exposed sap over a measured distance of a quarter of a mile, within 5 minutes, flying upwind. Fermented sap a week or more old is much less acceptable and its range of attractiveness is much diminished. (This reaction is utilised in the form of trap-trees for the control of the pest.) Water is also a necessity to the beetle and without it life is reduced by ten days or more. The beetle drinks from a droplet of water by scooping movements of the palpi and the hypopharynx. The excrement is a yellowish somewhat oily precipitate. In captivity beetles have been kept alive for 10 days to a fortnight without solid food or water.

Pairing: The sexual activities of the male occupy a great part of his life. Rivalry between males leads to fights in which antennae and legs are bitten off. The bite of the large pointed mandibles is powerful and will draw blood from the human finger. In captivity large males have been observed to monopolise several females driving off smaller males in much the same way as a stag or boar does. When courting a female tbe male sometimes halts and raises his body to the full extent of his legs and stridulates by vibrating the inner posterior edge of the pronotum against the scutellum. (Both sexes stridulate when alarmed or defensive.) When pairing the male mounts on the back of the female clasping her humeri with the claws of the fore-tarsi, and pressing his

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Fig. 56. The sal borer, Hoplocerambyx spinicornis.

Log of *Shorea robusta* split longitudinally along a diameter to show the pupal chambers of *Hoplocerambyx spinicornis* in the heartwood; 4 beetles and 1 larva are seen in place in their pupal chambers; 3 calcareous opercula are intact at the mouths of the prepupal tunnels. NB. The log was photographed while standing upside down; the normal trend of a pupal chamber is downwards in the standing tree; see fig. 42, No. 7, which shows the prepupal tunnel and pupal chamber diagramatically.

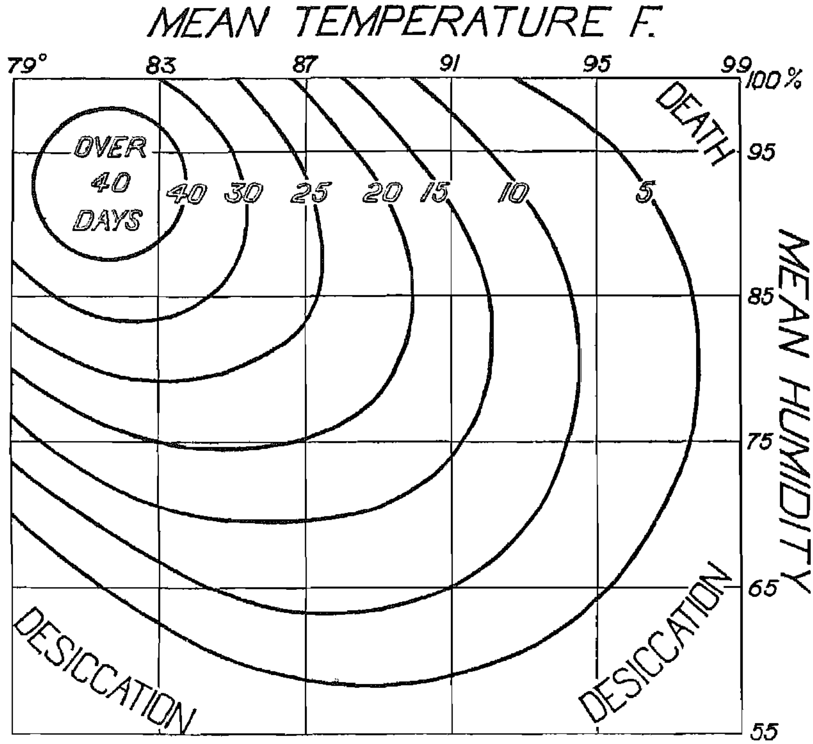

Fig. 57. Graph showing the zones of maximum life of beetles of *Hoplocerambyx spinicornis* at different combinations of temperature and relative humidity. Mean temperature during life in degrees Fahreinheit is the mean of the daily maxima and minima; mean relative humidity percentages during life as measured by a continuous recording hygrograph. Note that low humidities are unfavourable to the continued existence of the beetle at both low and high temperatures, and that in dry air the beetle dies by desiccation. High temperatures, by speeding up metabolism, reduce the length of life propoitionately. The most favourable atmospheric conditions are at temperatures round about 80°F and at relative humidities of 88 to 98 percent.

mandibles between the bases of the antennae of the female; the middle pair of legs of the male grasp the hind legs of the female. In this position and with exserted aedeagus the male is carried about by the female until she halts with exserted ovipositor and voluntarily accepts coitus. The actual pairing lasts only a few seconds and both organs are then retracted, but the male remains mounted. Sexes of very unequal size may pair successfully.

Pairing is frequently repeated and during the period a female is laying eggs, it usually alternates with the deposition of a few eggs.

Effect of humidity and temperature on length of life.

The longest life recorded in captivity is 49 days for the male and 38 days for the female. Dry atmospheric conditions are unfavourable to the life of the beetle which is considerably shortened or ceases; high atmospsheric humidities prolong life, increasing the average life of the population and permitting the maximum possible life. At temperatures above the threshold of activity life is shortened by increase of temperature within the normal limits of temperatures experienced during the monsoon season.

The mortality of beetles of *H. spinicornis* exposed to dry air and high temperatures is due to desiccation. The symptoms of progressive desiccation are observed first in the maxillary and labial palpi which lose flexibility and power of movement. The apical segments of the antennae and the tarsal segments of the hind legs are next affected becoming rigid. The whole antenna stiffens and cannot be vibrated. The hind legs become completely paralysed and the beetle for some time walks with two pairs of legs. In an advanced stage of paralysis of the organs control of direction is lost and the beetle moves unsteadily round and round in an irregular circle. The dead beetle is as light and "set" as a pinned specimen. Mortality of *H. spinicornis* exposed to saturated air is preceded by a swelling of the abdomen and a rapid decay of the tissues. A dying beetle is recognisable by the production of a foul smell and the dead beetle rapidly putrifies.

Optimum atmospheric conditions: The maximum life of about 50 days is reached at about 93 percent relative humidity and 82°F., when the individual is exposed to these conditions throughout life. Under natural conditions the beetle encounters a wide range of diurnal and nocturnal variations but it does not expose itself voluntarily to temperatures higher than normal shade temperature or to saturated highly heated air. The possible length of life of a beetle in nature depends not only on the weather but also on its ability to find shelter and food ; nevertheless the diagram in figure 57 gives a picture of the effect of weather on longevity. The concentric boundary lines indicate the expectation of life, e.g., the possible maximum life at various combinations of humidity and temperature. Life is possible for a day or two at a humidity as low as 55 percent as well as at a temperature as high as 100°F. The possible longevity increases with rise in humidity upto a certain percentage, which is less with each degree of increase in temperature, thereafter falls with increasing humidity. Similarly longevity increases with fall in temperature down to a certain degree, which is higher with each decrease of humidity, and thereafter falls with decreasing temperature.

Effect of humidity and temperature on oviposition

Oviposition: The female begins to lay eggs 7 to 9 days after the first fertilisation and thereafter may lay numerous eggs without a second fertilisation or may pair repeatedly during active oviposition. The maximum number of eggs laid by one female is 468, and the maximum oviposition-period (time from deposition of first to deposition of last egg) is 30 days. Eggs are laid singly, placed by means of the extended ovipositor as deeply as possible in cracks, holes and overhanging flakes of bark. If placed in an exposed place the female may rectify the error by moving the egg with the palpi to a more suitable spot. The preferred sites for oviposition are the underside of logs on the ground and the shady side of the trunk and branches of standing trees. The number of eggs laid in one day varies very widely; the maximum recorded is 183.

(a) *Humidity:* The following figures give the maximum number of eggs laid at different percentages of atmospheric humidity to which the females were exposed irrespective of the concurrent temperatures:—

Humidity percent	...	55	61	66	78	89	91	100
Number of eggs	...	0	42	83	273	416	465	420

At a humidity of 55 percent no eggs are laid and between 55 and 70 percent the number of failures to oviposit is high and the number of eggs laid by ovipositing females is low. Above 75 percent (at the most favourable temperature) over 200 eggs may be laid and the possible maximum increases with increasing humidity but between 90 and 100 percent there is a slight falling off. Saturation and subsaturation of the air is unfavourable to the deposition of eggs in large numbers by the population as a whole, although the maxima may be be laid by some individuals.

(b) *Temperature:* The effect of temperatures within the normal range of the monsoon season is less marked on the fecundity of the female than is the effect of humidity. Eggs are not laid at low temperatures which make the female inactive; the lowest mean temperature during life at which egg-laying has been recorded is 79°F. and the highest 95°F.

Optimum atmospheric conditions: The optimum combination of relative humidity and temperature of the air during the life of the female for fecundity, i.e., that at which the greatest total number of eggs is laid, is the same as that for longevity. The greatest total number of eggs recorded is 465 at 91 percent relative humidity and 82·7°F.; it is calculated that about 500 eggs might be laid by an individual subjected throughout life to the optimum for longevity. By plotting the data for maximum fecundity on the graph for zones of life [fig. 54] it is found that the humidity-temperature combinations producing a progressive variation in length of life also produce a progressive variation in fecundity in the same direction but not directly proportional.

Thus, in the life zone of—

over 40	days,	450—500	eggs may be laid.
30—40	,,	400—450	,, ,,
25—30	,,	350—400	,, ,,
20—25	,,	300—350	,, ,,
15—20	,,	200—300	,, ,,
10—15	,,	100—200	,, ,,
5—10	,,	1—100	,, ,,
1—5	,,	*Nil*	,, ,,

The maximum number of eggs possible for a life zone may be laid by an individual whose actual life is less than the maximum possible for a given humidity-temperature combination. The factors which are favourable to prolonged life of the beetle are also favourable to the production of larger numbers of eggs; at the extreme conditions under which life is possible for a few days only, the deposition of eggs is impossible.

Hatching of eggs: The normal incubation-period varies from 3 to 7 days with a mode of 4 days. Under very dry conditions the egg does not hatch out but begins to shrivel within 10 to 14 hours and is completely desiccated in 24 to 36 hours; the shrinking takes place in longitudinal folds leaving the middle of the egg empty and transparent with specks of yellow yolk at the ends. Exposure to dry air for 3 or 4 hours is sufficient to destroy the power of germination. Under very wet conditions eggs are liable to be destroyed by mould. An egg attacked by fungus wrinkles and is overgrown with yellow mycelium which after 6 to 10 days produces long stalked fruiting bodies that release a dust of dark yellow spores. There is no difference in the percentage of hatching or the length of the incubation-period in eggs kept in darkness or in bright light. The percentage of eggs hatching under normal atmospheric conditions varies from 75 to 100 percent and is on the whole between 80 and 90 percent.

Early larval stages

The conditions under which the first stage larva can establish its tunnel in the bark of a living tree are of primary importance in determining the origin and progress of epidemics. If a single larva bores into the living bark it is overwhelmed by the resinous sap that flows into the larval tunnel. The maximum quantity of resin that can be produced at a seat of local irritation depends on the vigour of the tree. If the points of irritation are excessively numerous resin is not produced in sufficient quantity to overwhelm each larva and many or all of them survive. Hence arises the paradox which has puzzled many forest officers and formed the basis of opposite schools of thought—a perfectly healthy sal tree is able to resist the attack of *Hoplocerambyx*, yet *Hoplocerambyx* is able to kill a perfectly healthy sal tree. Each of these statements is literally true. The qualifying factor is the ratio of the population-density of the borer to the resin-production capacity of

the tree.

An attacked tree which has defeated the attack is recognisable by patches of resin (ral) on the bark; at first these are shining and glassy, later they become opaque and yellowish; where the struggle between borer and tree has been prolonged the outflow of ral may cause the formation of pendent stalactites of solid resin often over a foot long with corresponding splashes of stalagmites on the ground beneath the crown branches.

250 eggs is the average laying of one female and 180 eggs may be laid in one day. It is therefore not improbable that a visitation of 200 fertile females during the season might result in the deposition of 50,000 eggs on one tree. The maximum number of living *Hoplocerambyx* larvae actually found in a sample tree (bole and crown) is 1378 in January, and the maximum emergence of beetles from a sample tree is estimated at 430. It is evident therefore that a reduction of 99 percent of the initial population can occur. The reduction due to the drowning of the early stage larva in resin varies with the power of resistance of the tree. In trees with dead crowns the proportion of larvae surviving is higher in heavily attacked boles than in relatively lightly attacked boles, the increased ratio of survival being the result of mass-attack overcoming the resistance of the tree; the percentage of larvae surviving in the crowns of such trees is also very high. In trees with green crowns the average mortality of early stage larvae is still higher in the lightly attacked boles, and is high or the attack may fail altogether in the crowns.

Later in the season, at the beginning of the pupal period, traces of early larval work are mostly obliterated and it is not possible to assess the percentages of dead and surviving larvae in killed trees. But in trees with green crowns, i.e., still living, the larval mortality is 60–80 percent.

A sal tree of which the resistance is strong enough to produce copious outflow of resin may cause a mortality of 85 to 100 per cent in the first instar. Many trees which had been attacked in three successive years have survived. Further data are given in the section on Control Measures in Part Two.

Effect of humidity and temperature on the late larval and pupal stages.

(*a*) *Humidity*: The mature larva of *H. spinicornis* is able to withstand considerable loss of body-moisture and survive for several weeks before succumbing. The rapidity with which death follows desiccation is not proportional to the amount of moisture lost. In the dry season shortly before pupation the larva can withstand exposure to moderately dry conditions for short periods (up to 3 weeks) and pupate and transform to a beetle. Larvae can withstand exposure to saturated atmosphere for several months and survive, and can transform in a saturated atmosphere with

free moisture, provided that the mechanical facilities for ecdysis are favourable.

(*b*) *Temperature*: Larvae subjected to lower temperatures than normal pupate later than normal, and pupation may be delayed for 3 weeks. Low temperatures may prolong the pupal stage by 1 or 2 days.

Atmospheric humidity during the dry season and early monsoon does not affect the rate of development of the larva and pupa sufficiently to accelerate or retard appreciably the date of transformation to beetle, while effective temperature on the contrary does appreciably accelerate or retard the date of transformation to beetle.

Emergence-period.

At Dehra Dun the earliest recorded emergence is 7th June and the latest 23rd September; these variations are due to the weather conditions of the different years.

Emergence-percentage and rainfall: In the following table the rate of emergence is compared with the amount of rain falling after 1st June showing the possible minimum and maximum percentages of the total population that may emerge with a given quantity of accumulated rainfall, irrespective of any time-period.

Inches of rain accumulated since 1st. June at Dehra Dun, U.P.	Percentage of beetles emerged since 1st. June. Possible minimum.	Possible maximum.
5	7	30
10	29	58
15	50	76
20	64	88
25	74	95
30	83	98
35	90	100
40	94	..
45	96	..
50	99	..
65	100	..

100 percent emergence may theoretically be effected with a minimum of 35 inches of rainfall or with a maximum of 65 inches. The rate of emergence is affected by the rate of precipitation but is not directly proportional to it. But the amount of precipitation cannot be considered without reference to the period during which it falls and to the other meteorological factors of the locality. The relationships of the three variables,—emergence-percentage, accumulated rainfall and date,—are shown in fig. 58. The zones of probable emergence are applicable only to the weather conditions of Dehra Dun; similar graphs prepared for other climatic regions would show different boundaries for the emergence-zones in the same framework of rainfall : date.

EMERGENCE PERIOD OF H. SPINICORNIS

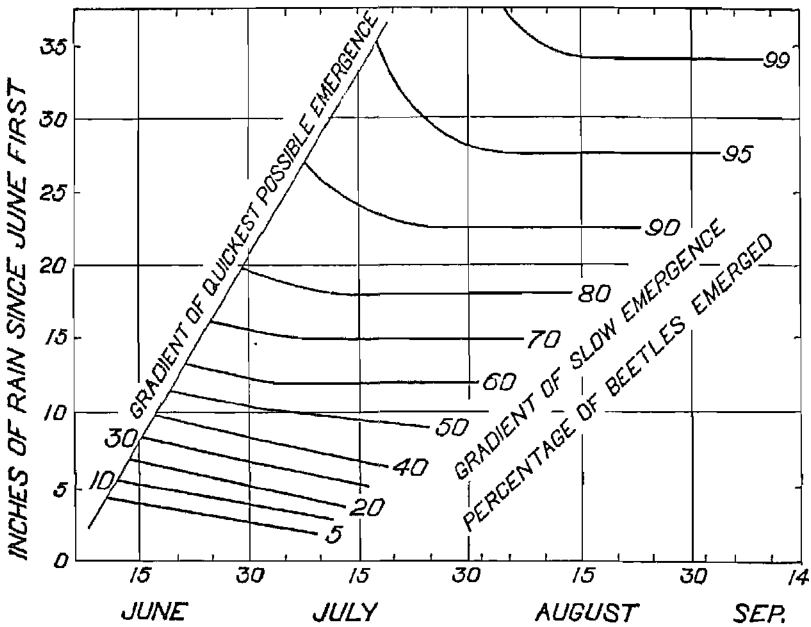

Fig. 58. Correlation of the number of inches of rain falling since June 1st., the date and the percentage of the total annual population of beetles of *Hoplocerambyx spinicornis* emerged. The zones of emergence-percent reach the quickest possible rate in the gradient on the left, and the slowest recorded rate in the gradient on the right. From this graph one may read off the percentage of the population that may be expected to have emerged on a given date with a given amount of rainfall since June 1st.

Thus, if only 10 inches of rain has fallen by the 15th July about 50 percent of the beetles will have emerged, but if 20 inches of rain has fallen about 83 percent of the beetles will have emerged. The gradient of quickest possible emergence is obtained by early and plentiful rain in June and the first half of July, and the gradient of slow emergence results from a late and deficient monsoon in July. Up to about sixty percent of the total emergence and up to about 12 inches of accumulated rainfall, the time-factor and the rainfall-factor are each mutually important in determining the rate of emergence of the beetle. After about 60 percent has emerged the rate of emergence is entirely influenced by the amount of rain falling and is not appreciably influenced by the lapse of time. Hence breaks in the monsoon in July and August have a marked effect on the emergence of the late broods.

Since the monsoon precipitation does not fall at a uniform rate *Hoplocerambyx* does not emerge at a uniform rate throughout its emergence-period. Each shower or storm brings out a fraction of the total population, and if a day or a few days without rain intervenes the emergence of the beetles ceases. A typical graph of emergence is shown in fig. 59 and superimposed on it is the graph of rainfall. The two quantities are grouped by 3-day periods. The coincidence of the peaks of increased beetle emergence with peaks of rainfall and of the troughs of reduced or no emergence with troughs of rainless days is at once evident. It is also evident that relatively higher instalments of rainfall are required to accelerate the emergence of the backward individuals.

Emergence-period in Central Provinces: The normal June–July rainfall at Baihar, Balaghat, C.P., is less than at Dehra Dun and 100 percent emergence is reached with 26 inches of rain. At Dehra Dun complete emergence is reached with 35 inches of rain. Compared by calendar dates the rate of emergence at Baihar is more rapid than the normal rate at Dehra Dun for the same quantity of accumulated rainfall. The table below compares the actual percentage-emergence at Baihar with the theoretical emergence at Dehra Dun for the same progressive accumulation of rainfall; the data for Dehra Dun are taken from the diagram in fig. 58.

	June			July			August		
Date	9	18	27	6	15	24	2	11	
Accumulated rainfall, Baihar	0·04	3·52	4·69	7·05	9·82	18·61	20·37	25·65	Inches.
Percentage of beetles emerged, Baihar, C.P.	0	1	24	56	88	97	99	100	Percent
,, ,, Dehra Dun U.P.	0	5	15	37	50	82	86	93	Percent

There is therefore no fundamental difference in the emergence-period of *Hoplocerambyx* in the Central Provinces and in the United Provinces.

Emergence-period in Assam-Bengal: Stebbing (1914, p. 322) records beetles in abundance in Goalpara, Assam, in the second half of May with oviposition on 14th May; the latest beetles were taken at trap trees on 17th July. In Kurseong, Bengal Ahmad (1935, p. 330) trapped beetles from 19th May to 17th July. Emergence in Assam-Bengal evidently occurs earlier in conformity with the earlier rainy season.

Summary: The initial date of emergence and the rate of emergence of the first 60 to 70 percent of the total annual population of *H. spinicornis* is influenced by the initial date of the preliminary showers of the monsoon and by the quantity of monsoon rainfall in June and July; the earlier and more abundant the rains, the earlier and quicker the emergence. The effect of rainfall is presumed to be through the moisture-content of the wood

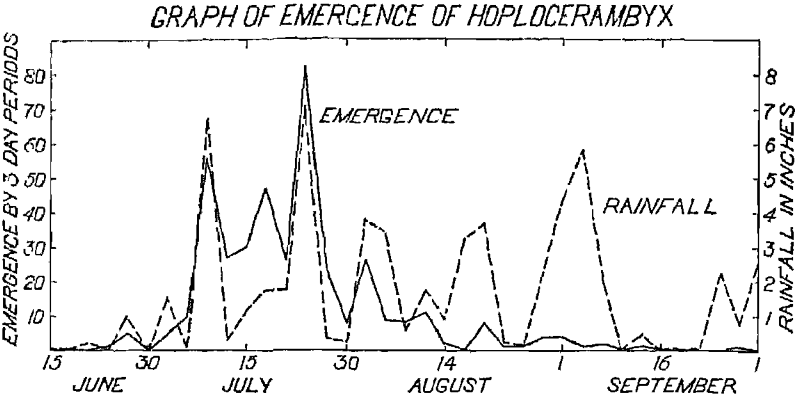

Fig. 59. Graph of the emergence-period of *Hoplocerambyx spinicornis* from *Shorea robusta* showing percentages of the total annual population of beetles emerging at 3-day intervals correlated with the rainfall for the same period by 3-day intervals. Note that the emergence does not start until the first monsoon showers occur and that the subsequent subsidiary peaks of beetle emergence coincide with peaks of rainfall.

containing the pupal chambers of the beetle. Wood which has a high moisture-content at the beginning of the rains, owing to slow seasoning under shelter (or artificially raised by soaking the wood) produces beetles earlier and more rapidly than wood which has a low moisture-content, owing to rapid seasoning by exposure or by conversion. The increase in the moisture-content is more rapid in wood which absorbs moisture directly by exposure to rain than in wood which is sheltered and absorbs its moisture only from the air. The moisture-content of the wood acts primarily on the immature beetle in the pupal chamber, since the mature larva and pupa can withstand very wide variations in the moisture-content of the wood and the air.

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Hypoeschrus indicus, C, 12-20 mm., in *Acacia catechu*, *Dichopsis grandis*, *Shorea robusta*. Emergence mainly in June.

Ischnodora macra in *Alnus nepalensis*.

Imantocera penicillata in *Ficus religiosa*.

Imantocera vicina, L, 20 mm., in *Myristica longifolia*.

Kunbir telephoroides, C, 6-8 mm., in *Bauhinia vahlii*, *Mallotus philippinensis*, *Ventilago calyculata*. Emergence May-July.

Leptepania indica, C, 5-7 mm., in *Albizzia lebbek*.

Leptura rubriola, C, 10-15 mm., in *Abies pindrow*, *Cedrus deodara*, *Picea morinda*, *Pinus excelsa*, *P. longifolia*.

Beetle, C, 10-15 mm., male, black with basal half of elytra wine red or entirely black; female prothorax and elytra red. The adult occurs in April-August, emerging mainly in April-May. The larva is described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, pp. 34, 35.

Linda nigroscutata in *Pyrus malus*. Beetle, L, 17-20 mm., dull orange-yellow, with some black spots. The beetle eats the bark of shoots of apple trees girdling and killing them. A slit is bitten at right angles to the girdle and an egg is pushed between the inner bark and the wood. The larva bores in the twig for several inches above the girdle, hollowing it out. T. B. Fletcher, 1921, *Agr. Res. Ins. Bull.* 100, pp. 155, 156, pl. 82.

Lophosternus hugelii

Cedrus deodara, *Dalbergia sissoo*, *Pyrus malus*, *Quercus ilex*, *Q. incana*, *Rhododendron* sp., *Sapium sebiferum*, *Shorea robusta*.

Beetle, C, 1 to 2 inches, chestnut-brown, shining, pronotum darker almost black at margins.

Life-history: This prionine is mainly a borer of stumps and dead or living roots of trees and is one of the species that is able to abandon wood and live in soil for a while. The larval workings in dead tree trunks and stumps are deep excavations in the sapwood from which a tunnel is carried into the heartwood and leads to a vertical chamber large enough for a larva two to three inches long. A considerable quantity of wood-dust and frass is thrown out in a heavy attack and accumulates in a heap. The dead or injured parts of the trunk and roots of a living tree may be attacked.

L. hugelii is a pest of apple orchards in Kashmir and Kumaon, United Provinces; the larvae of all ages bore into the living healthy roots of apple trees feeding externally at first but causing deep injury in the later stages and sometimes completely severing large roots from the base of the tree. It also attacks the roots of seedlings of deodar and other small trees, in the hills and the roots of large trees of sal and shisham in the plains.

Eggs are laid in the soil about one third of an inch deep mainly during July, one female laying as many as 600 eggs during an oviposition-period of four weeks. Moist soil, poor in organic matter is preferred to a rich humus soil or a dry soil for oviposition. Hatching takes three to six weeks and the young first instar larva may live in moist soil without food for three weeks. It does not travel very far and unless a root is soon found it does not survive. It works along the root often from the base towards the apex. If the larva leaves a root it rarely travels far enough or in the right direction to find another root, but can survive for about three months in the soil. In consequence the larval mortality is high. Pupation occurs in the soil in a cell made of earth, smoothed and cemented within. The life-cycle probably lasts upto four years. Emergence occurs mainly in June-July; the beetles come to light, and may live for three months.

Annual Reports, Hill Fruit Research Station, Chaubattia, U. P., for 1935-36 and later.

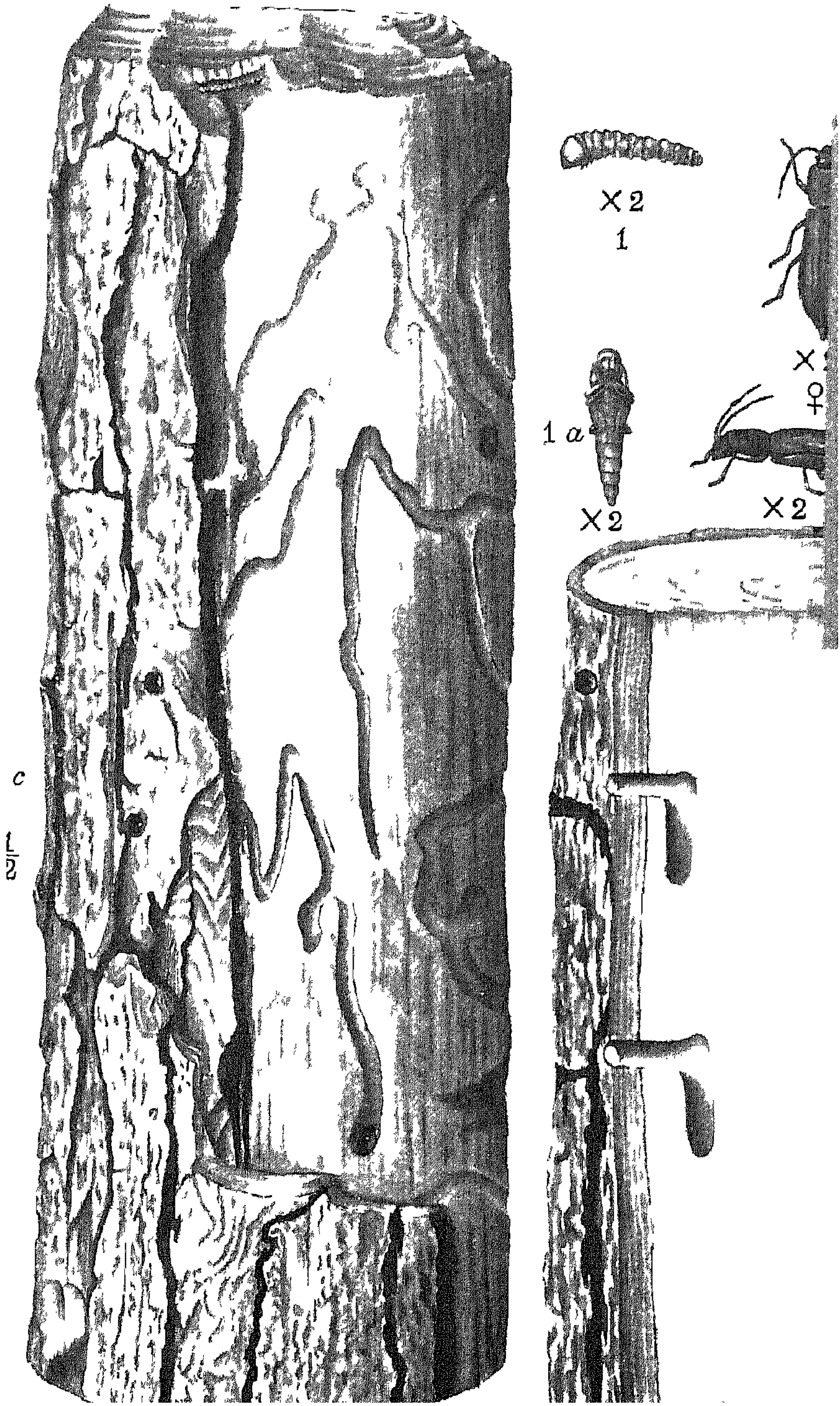
The larva is described by Beeson, 1919, *Ind. For. Rec.*, VII, v, pp, 19, 20, and Gardner, 1927, *tit. cit.*, XIII ii, p. 33.

Lophosternus socius in *Cryptomeria japonica* in Bengal.

Macrochenus guerinii in *Bombax malabaricum*, *Ficus elastica*, *F. religiosa*, *Lagerstroemia flos-reginae*, *Stereospermum chelonoides*. Bengal to Thailand. Beetle, L, ⅞rs to 1 1/8th inches, ashy

Fig. 60. Tunnels of Nothorrhina gardneri in Pinus longifolia.

Log of *Pinus longifolia* (about half natural size, 1*c*) showing larval tunnels of *N. gardneri* on surface of sapwood, bark and wood-dust filling removed; 1*d* pupal chamber, natural size, in longitudinal section; 1, 1*a*, 1*b* larva, pupa and female.



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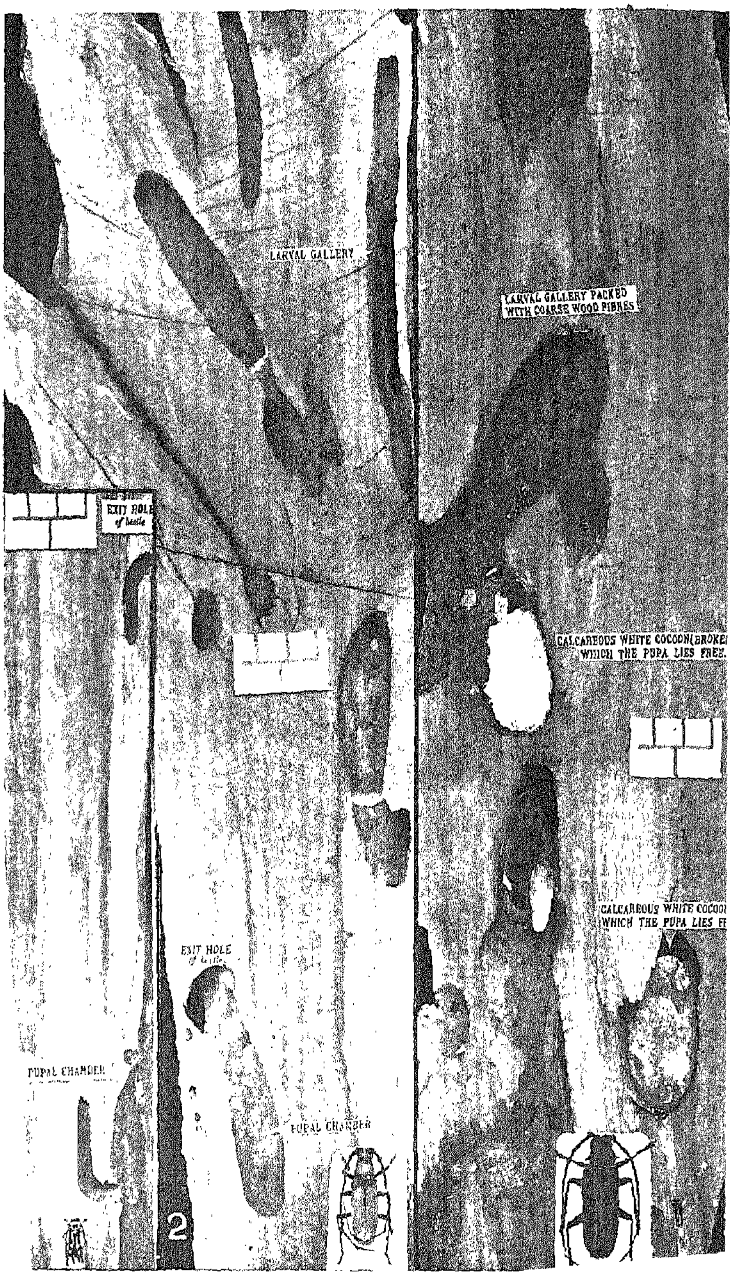
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blue, with scattered black spots, base of elytra ferrugineous, prothorax black with fine whitish bands. Emergence occurs in April–May. The pupal chamber is vacated by the beetle through an imaginal tunnel from its lower end. The larva is described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, p. 50.

Macrochenus tigrinus in *Artocarpus hirsuta, A. integrifolia, A. nobilis.* Burma and south India. Beetle, L, 3/5ths to 1 1/10th inches, greyish or ashy, elytra with black spots, head and prothorax with black longitudinal bands [fig. 69, No. 5]. Emergence occurs in April–October. The pupal chamber and exit-hole are illustrated in fig. 69.

Macrotoma crenata in *Bombax malabaricum, Eucalyptus* sp., *Mangifera indica, Quercus dilatata, Q. incana, Shorea robusta, Tamarix articulata, T. gallica.* Beetle, 1 1/8 to 2¼ inches, dark brown, elytra somewhat lighter becoming darker towards the base, having a rough pitted surface.

The species occurs throughout India, in the dry forests of Sind and in oak forests of the Himalayas upto 6,000 feet and in the wet regions of Ceylon and Burma. It bores in freshly felled hardwood as well as soft tindery wood. The larval galleries run irregularly in the wood, penetrating deep into the core and are about ¾ to 1¼ of an inch across, packed with a fairly compact mass of fibres which are finer and smaller in the earlier galleries. The larva of *Macrotoma palmata* has a proventriculus adapted to grinding up coarse wood-particles, and is also able to secrete cellulose; these characteristics explain its ability to feed on heartwood. The pupal chamber is an irregular excavation about 4 by

Fig. 61. Damage to wood by Cerambycidae

No. 1. *Glenea lecta*—Longitudinal section through wood of *Magnolia pterocarpa* showing pupal chamber and beetle of *G. lecta*; the upper pupal chamber is directed downwards and the lower pupal chamber is directed upwards; the exit-hole of the chamber is at the surface of the sapwood (bottom right).

No. 2. *Massicus venustus*—Longitudinal section of bole of *Hopea parviflora* showing larval tunnel, pupal chamber and beetle of *M. venustus*; the wood-dust has fallen from the larval tunnel (upper right); the pupal chambers are directed upwards, obliquely and downwards; the calcareous operculum at the mouth of the pupal chamber has been broken by the exit of the beetle and only the rim remains.

No. 3. *Plocaederus obesus*—Longitudinal section of bole of *Lannea grandis* showing larval tunnel, pupal chamber, calcareous cocoon and beetle of *P. obesus*; the larval tunnel is packed with coarse wood-fibres; one calcareous cocoon is intact (below) and one is broken showing the smooth interior (above); sapwood surface on right.

All photographs to the same scale as indicated by the inch-centimetre scale.

2 inches containing loosely aggregated masses of fibres. The exit-tunnel narrows very much towards the extremity—from 1 1/4 to 5/8ths of an inch—and runs almost horizontally to the outside. The exit-hole is subrectangular, 5/16ths by 9/16ths of an inch. Pupation occurs in the hot weather and the beetles are on the wing from June to September. The generation is annual. The larva and pupa are described by Beeson, 1919, *Ind. For. Rec.*, VII, v, pp. 10–12, pl. i, fig. 7.

Macrotoma plagiata in *Eucalyptus robusta, Heritiera fomes, Juglans regia, Pyrus malus.*

Beetle, C, 1 1/4r to 1 4/5ths inches, dark brown resembling *M. crenata*. The larval galleries run irregularly in the heartwood, across as well as with the grain and are fairly tightly packed with fibres and wood-dust; the diameter frequently reaches 3/4rs of an inch. There are no definite galleries between the sapwood and the bark. The full-grown larva is 2 inches long. The pupal chamber is an irregular excavation without definite shape, produced by a simple expansion of the larval tunnel and is padded with wood-fibres to round off any irregularities. The exit-hole is subrectangular with rounded corners. The life-cycle may be completed in a year, but under unfavourable conditions, as in dry wood, it may be prolonged to as much as five years. The beetle emerges in June to August each year. The beetle, larva and pupa are described and figured by Beeson, 1919, *tit. cit.*, VII, v, pp. 7–10, pl. i, figs. 1–6, 8.

Macrotoma spinosa in *Casuarina equisetifolia, Lannea grandis.*

Beetle, C, 1 4/5ths to 2 2/3rds inches, dark brown, elytra rusty brown. The adults occur in June–August. A heartwood borer of habits similar to the two preceding species.

Margites exiguus in *Anogeissus acuminata, Aporosa villosula, Terminalia pyrifolia*. This sapwood borer, C, 12–16 mm., forms a pupal chamber similar to that of *Margites modicus*. Emergence in May in Burma.

Margites modicus in *Anogeissus acuminata, A. latifolia, Shorea robusta, Terminalia chebula, T. tomentosa.* Beetle, C, 12–16 mm., dark brown, head and prothorax nearly black. Indian Peninsula and Gangetic plain.

The larva bores the sapwood. The pupal chamber is closed by a partition of calcium carbonate attached to a narrow thin band on the wall. The life-cycle is annual and the beetle emerges in May–July, (60 percent in June), i.e., before the establishment of the monsoon. Logs lying in the sun are more liable to attack than those lying in the shade. Trees felled more than seven months before the flight-period are not usually attacked.

Massicus unicolor in *Quercus griffithi, Q. mespilifolia*. Beetle, C, 2 1/5th inches, dark brown, with an ashy yellow pubescence;

pronotum corrugated. The larva bores large tunnels in the heartwood and forms an operculum to its pupal chamber; the adult occurs in August. The larva is described in 1925, *Ind. For. Rec.*, XII, ii, p. 102.

Massicus venustus in *Hopea parviflora* in south India. Beetle, C, 1 1/2 to 2 1/4 inches, uniform tawny brown [fig. 61, No. 2] A heartwood borer of stumps, fire-scorched poles and trees and overmature trees. In fig. 61 are illustrated the larval tunnel, pupal chamber and calcareous operculum closing the chamber. Like *Hoplocerambyx spinicornis* it is primarily a borer of dead wood but is able to establish successfully in living trees the resistance of which is lowered by various causes. Such are killed by the girdling effect of a mass-attack. The life-cycle is apparently annual with emergence in both monsoon seasons in south India, but emergence may be delayed upto a year thereafter.

Meges marmoratus in *Castanopsis tribuloides*, *Quercus griffithii*. Beetle, L, 2 4/5ths inches, black, mottled with greyish and brown markings on the elytra, pronotum greyish with a black median triangular patch. Bores in green *Castanopsis* trees.

Megopis buckleyi in *Quercus dilatata*, boring the rotten wood.

Megopis cingalensis in *Acacia melanoxylon*, *Eucalyptus globulus*, *Michelia nilagirica*, *Rhododendron arboreum*, *Semecarpus thwaitesii* in south India and Ceylon. Emergence in April. The larva is described by Gardner, 1931, *Ind. For. Rec.*, XVI, iii, p. 165.

Megopis tibialis in *Evodia fraxinifolia*, *Ilex hookeri*, *Lindera pulcherrima*, *Machilus odoratissima*, *Symplocos theaefolia*. Beetle, C, 1 to 1 7/8ths inches, dark brown, elytra reddish-brown, glossy. A borer of old or decaying wood; the life-cycle of this prionine is annual with emergence in April, May, mainly May. The larva is described by Gardner, 1931, *tit.cit.*, p. 164, figs. 1, 2.

Melanauster beryllinus in *Quercus dealbata*. Beetle, 12–23 mm., pale green with black spots or broken horizontal bands on the elytra, antennae ashy, the joints tipped with black.

The beetle lays its eggs on living healthy branches or stems of young trees and the larva bores round the branch between the bark and sapwood. The plant reacts by forming a corrugated cankerous swelling over the site of the larval tunnel. Usually only one larva inhabits each canker. The pupal chamber is formed in the heartwood. The beetle emerges by cutting a short tunnel from the end of the pupal chamber straight out to the exterior; the exit-hole is circular. There may be several cankers, upto 7, on one branch. The life-cycle is annual and the beetles emerge in May, June. The larva is described in 1927, *tit. cit.*, XIII, ii. p. 53.

Merionoeda nigriceps in *Dendrocalamus strictus*.

Merionoeda phoebe in *Phoebe lanceolata*.

Mesocacia assamensis, L, 15 mm., in *Dipterocarpus macrocarpus*, *Shorea robusta*. Emergence of this sapwood borer occurs twice a year with facultative prolongation to an annual cycle.

Mesosa bifasciata, L, 8 mm., in *Bauhinia vahlii*.

Mesosa bimaculata, L, 12 mm., in *Acrocarpus fraxinifolius*, *Albizzia odoratissima*.

Mesosa columba in *Artocarpus integrifolia*.

Mesosa griseiventris, L, 8–16 mm., in *Dalbergia paniculata*.

Mesosa indica in *Acacia pennata*, *Bauhinia purpurea*, *B. vahlii*, *Bombax malabaricum*, *Buchanania latifolia*, *Dendrocalamus strictus*, *Lannea grandis*, *Mallotus philippinensis*, *Scutia indica*, *Shorea robusta*, *Terminalia tomentosa*. Assam to south India.

Beetle, 18–20 mm., greyish-brown variegated with dark brown angular markings. This species is a borer of dry sticks, woody climbers and branches of small dimensions as well as of the sapwood of logs; it has also been found boring green bamboo. The life-cycle is annual, with emergence in May-August with 40 percent in June, and 40 percent in August. Development may be delayed to the second and third years. The larva is described in 1931, *Ind. For. Rec.*, XVI, iii, p. 186 (*Mesosa ominosa* Pasc.).

Mesosa rosa in *Mallotus philippinensis* in south India and Ceylon.

Mesosa setulosa, 10 mm., in *Prunus racemosa*.

Mesosa gardneri in *Bauhinia retusa*, *B. vahlii*, *Mallotus philippinensis*, *Pavetta indica*. Beetle, L, 12–15 mm., greyish-brown variegated with darker and lighter spots. The life-cycle of this sapwood borer is annual with prolongation to the second or third year in dry wood; emergence occurs in May–July, mainly June.

Moechotypa sikkimensis, 15 mm., in *Acacia gageana*, *Albizzia* sp., *Ficus glomerata*, *Mucuna imbricata*.

Moechotypa verrucicollis in *Acacia caesia*, *Acacia* sp., *Albizzia lebbek*, *A. odoratissima*, *Hevea braziliensis*. Burma to Ceylon. Beetle, L, 1 inch, reddish-purple above, pink below, elytra with a grey X marking. The life-cycle is apparently annual with emergence in July–September, mainly August. The larva and pupa are described in 1931, *tit. cit.*, XVI, iii, pp. 192, 193, figs. 50–53.

Molorchus darjeelingensis, 6–8 mm., in *Symplocos theaefolia*.

Molorchus hederae, C, 8 mm., in *Hedera helix*. Emergence occurs in March, April, mainly March; the life-cycle is annual with prolongation to the second year in dry wood.

Monochamus bimaculatus in *Aporosa villosula*, *Cedrela toona*, *Dalbergia sissoo*, *Eugenia jambolana*, *Ficus religiosa*, *Lannea grandis*, *Litsaea sebifera*, *Mallotus philippinensis*, *Phoebe lanceolata*, *Protium serratum*, *Randia dumetorum*, *Shorea robusta*, *Terminalia belerica*, *T. chebula*, *T. myriocarpa*, *T. tomentosa*.

Beetle, L, 12-20 mm., light brown, elytra speckled whitish with a chocolate median spot. A sapwood borer of dead twigs, poles and logs. The life-cycle is annual with prolongation to the second year. The pupal period is about 17-20 days in April, May. Emergence occurs in April, May (about 50 percent in each month) from material originating from Bengal; and in May-August (June 33 percent, July 47 percent) from material originating from Dehra Dun district. The earliest monsoon showers start the emergence but the borer prefers to breed in wood that is partially dried out and rejects green sappy wood. A series of trees of *Terminalia tomentosa* was felled, one each month, near Dehra Dun and half of the logs and branchwood of each tree was stored in the shade and half in the sun. None of the logs stored in the sun were attacked by *M. bimaculatus*. Of the material stored in the shade, trees felled during or just before the flight period were not attacked; those felled 2 to 10 months previously were attacked. The larva is described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, pp. 49, 50, fig. 49.

Monochamus gardneri, 10 mm., in *Terminalia myriocarpa*.

Monochamus griseatus in wood of living tea bushes, *Camellia thea*.

Monochamus nivosus in *Calotropis gigantea, Kydia calycina, Stephanotis floribunda*.

Beetle, L, 23 mm., brown with a shining greyish pattern on the elytra. Associated with *Calotropis gigantea* as a borer of the dead or dying woody parts. Beetles occur between May and September. The larva is described in 1931, *tit. cit.*, XVI, iii, p. 181, fig. 25.

Monochamus ocellatus in *Mallotus philippinensis*.

Monochamus versteegi in *Amoora wallichii, Citrus aurantium*. Bengal to Sumatra.

Beetle, L, 4/5ths to 1 3/10ths of an inch, ashy blue with scattered black spots. This species is a minor pest of orange cultivation in Assam; it is probably the species which attacks living *Amoora wallichii* in plantations in Assam. Eggs are laid on stems or small branches of young living *Citrus aurantium* and the larva bores a long tunnel up and down the stem. Emergence occurs in April-May with an annual life-cycle. The larva is described in 1931, *tit. cit.*, p. 182.

Monochamus westwoodi in *Evodia fraxinifolia*. Beetle, L, 1 3/10ths of an inch, speckled black and greyish. The larva is described in 1931, *tit. cit.*, p. 182.

Morimopsis lachrymans in *Acer campbelli, Juglans regia, Litsaea citrata, L. elongata, Machilus odoratissima*. Beetle, L, 15-20 mm., cinnamon-brown, variegated with reddish-brown and yellow. Beetles occur in the dead wood in September and emerge in April. The larva and pupa are described in 1931, *tit. cit.*, p. 180, 177.

Morimus inaequalis in *Ficus* sp. and a climber. Beetle, 1 inch, yellowish-brown, pronotum with a pair of dark spots, elytra each with 2 irregular dark spots. The larva and pupa are described in 1931, *tit. cit.*, pp. 179, 180, fig. 28.

Mutatocoptops similis in *Dipterocarpus macrocarpus.*

Myagrus hynesi in *Ficus glomerata*, *Ficus* sp., *Grewia* sp. Beetle, L, 17 mm., brown, elytra speckled with cream, sides of pronotum dull white. The larva and pupa are described in 1931, *tit. cit.*, p. 184, figs. 26, 27.

Necydalis indica in *Quercus dilatata*, *Q. incana*, *Q. semecarpifolia.* Beetle, C, 10–16 mm., head and thorax black, elytra almost black in male, uniformly dark red in female. A borer of dry wood and stumps.

Neocallia pubescens in *Zanthoxylum rhetsa.*

Neocerambyx paris, C, 2–3 inches, in *Quercus* sp., in Burma.

Neosybra ropicoides, L, 7 mm., in *Acrocarpus fraxinifolius.*

Nida kala, C, 10 mm., in *Phoebe lanceolata.*

Niphona assimilis in *Calotropis procera.* Beetle, L, 9–16 mm., greyish mixed with straw-yellow. Emergence occurs in April and September, October. The life-cycle is biannual with prolongation to a full year.

Niphona cylindracea in *Casuarina equisetifolia*, *Terminalia paniculata*, *T. tomentosa.*

Niphona hookeri in bamboo.

Niphona malaccensis in *Acacia caesia*, *Bombax malabaricum*, *Careya arborea*, *Casuarina equisetifolia.* Beetle, L, 12-17 mm., reddish-brown variegated with chocolate markings. Emergence from dry sticks occurred in June–October, mainly August.

Niphona stramitosa, 15 mm., in *Calotropis procera.*

Noserius indicus in *Xylia dolabriformis* in south India.

Noserius tibialis C, 12-18 mm., in *Xylia dolabriformis* in Burma.

Nothorhina gardneri in *Pinus longifolia* in the north-west Himalayas.

Beetle, C, 8-12 mm., rufous brown or black. The larva is a borer of the inner bark and sapwood of dead branches and trunks making long irregular tunnels packed with dark brown dust. The mature larva in spring bores into the wood for about three-quarters to one inch ; the pupal chamber is parallel to the axis of the log and the prepupal tunnel is oblique or at right angles to it, closed above with wood-fibres. The beetle escapes through the prepupal tunnel, [fig. 60]. The life cycle is annual with emergence in March–June (53 percent in June).

Illustrations of the stages and the damage are given by Stebbing, 1911, *Ind. For Mem*, 2, 2, p. 14, plate XVIII and 1914, *Ind. For. Ins.*, pp. 281-283, plate XVIII under the name of *Nothorrhina muricata* Daln.

Nupserha bicolor in *Phaseolus aconitifolius*, *P. radiatus*, *Vigna catjang.* Beetle, L, 8 mm., testaceous, apical half of elytra

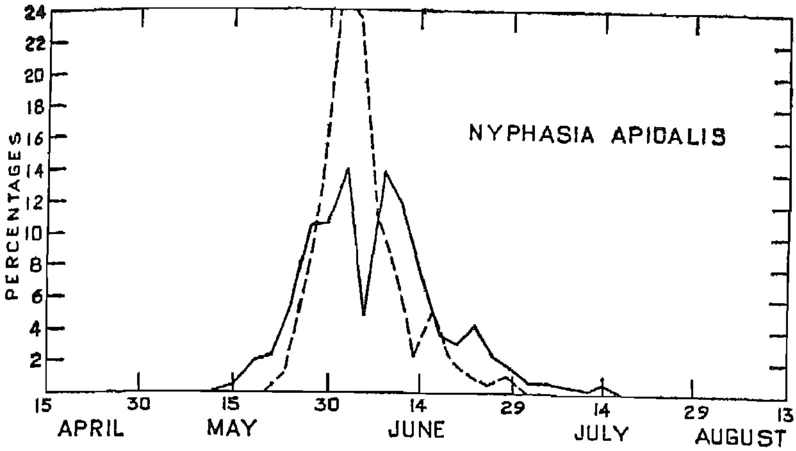


Fig. 62. Graphs of the emergence-periods of *Nyphasia apicalis* from *Terminalia tomentosa*, solid line, and from *Anogeissus acuminata*, broken line, showing percentages of the total annual population of beetles emerging at 3-day-intervals.

black. The adult girdles the young shoots of soy-bean and sann-hemp and oviposits on them; the larva bores the stem and lateral branches. The life-history is described by H. L. Dutt, 1915, *Bihar Agric. Jl.*, III, pp. 52-56; illustrations are given in *Ann. Rep. Imp. Ent.*, 1917-18, p. 98, plate 14, figs. 1 *a-d*.

Nupserha quadrioculata in *Convolvulus* sp. Emergence occurs in May–August (mainly May in south India). The larva is described in 1931, *Ind. For. Rec.*, XVI, iii, p. 197.

Nupserha variabilis in *Dalbergia* sp., *Gmelina arborea*, *Spondias mangifera*, *Tectona grandis*, *Thunbergia grandiflora*.

Beetle, L, 12-15 mm., head and thorax testaceous, basal half of elytra light bluish-green, apical half fulvous, apex black. The larva tunnels in the living stem of the climber *Thunbergia grandiflora* (or *laurifolia*) causing a large swelling or gall. When full grown the larva passes from the climber into the bark of the tree which is encircled by it and constructs a comma-shaped gallery about an inch to an inch and a half long in which pupation occurs. The beetle emerges by the original prepupal entrance-hole. Emergence occurs in April, May, mainly May.

Atkinson, 1931, *Burma For Bull.*, No. 26, p. 11, pl. XI (illustration of damage in teak and *Dalbergia*.)

Nyphasia apicalis in *Anogeissus acuminata*, *Shorea robusta*, *Terminalia tomentosa*. Beetle, C, 10-18 mm., tawny red with the apices of the elytra black or violaceous blue [fig. 49, No. 2].

This sapwood borer has an annual life-cycle which may be prolonged to the second year under adverse conditions. Emergence

is definitely pre-monsoon in May, June. Fig. 62 shows graphs of emergence from *Anogeissus acuminata* and *Terminalia tomentosa* by three-day intervals; in the latter case 25 percent of the total population took two years to mature. The larval tunnel and pupal chamber are illustrated in fig. 49.

N. apicalis is a sun-loving beetle, preferring freshly felled timber for oviposition but successful development is possible from eggs laid on logs up to four months after felling. Logs kept in the shade are much less liable to attack and produce smaller broods than do logs kept in the sun. Logs of trees felled over seven months before the flight-period are not attacked. The larva is described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, pp. 41, 42.

Nyphasia pascoei in *Anogeissus acuminata, Terminalia pyrifolia, T. tomentosa.* Beetle, C, 12-16 mm., tawny red with the elytra green, antennae and legs nearly black. Emergence occurs in May.

Oberea modica in *Clerodendron infortunatum.* Beetle, L, 13 mm., fulvous, sides of elytra dark brown, antennae black. Emergence occurs in June; the larva bores in the living stem. The larva is described in 1931, *Ind. For. Rec.*, XVI, iii, p. 197.

Oberea sericea in *Strobilanthes* sp., in Burma. [see fig. 63].

Obrium randiae in *Randia dumetorum.* Beetle, C, 8 mm., shining, fulvous, apex of elytra piceous. Emergence occurs in June.

Olenecamptus anogeissi in *Anogeissus latifolia, Ougeinia dalbergioides.* Beetle, L, 12-15 mm., reddish-brown, the elytra paler, with 3 sets of variable white markings on the elytron, and lateral white stripes on prothorax. Indian Peninsula.

The larval galleries of this log borer groove the sapwood slightly and the bark deeply; about half the bark is excavated, 1/8th to 1/12th of an inch deep. The galleries are irregular and are packed tightly at first with bark-dust, and later at the end of the larval period with wood-fibres. The sapwood is hardly grooved more than 1/12th of an inch by the mature larva and the sides of the gallery are concave. The entrance to the prepupal tunnel is oval. The pupal chamber runs from the oblique prepupal tunnel to about an inch below the surface; it is broad and curved and usually slightly longer than the antennae of the beetle. The exit-tunnel is circular in cross-section and takes off from the junction of the prepupal tunnel with the chamber. There are two generations a year in south India with emergence in May–July, and December–February. A portion of the brood is prolonged to an annual cycle.

Olenecamptus bilobus in *Artocarpus blumei, A. chaplasha, A. hirsuta, A. integrifolia. Bauhinia* sp., *Ficus bengalensis, F. carica, F. elastica, F. glomerata, F. infectoria, F. laccifera, F. religiosa, F. roxburghii, F. rumphii, F. tjakela, Litsaea polyantha, Mangifera indica, Morus indica.* Beetle, L, 10-15 mm., brown with round white spots [fig. 69, No. 7]. Widely distributed in the Oriental Region.

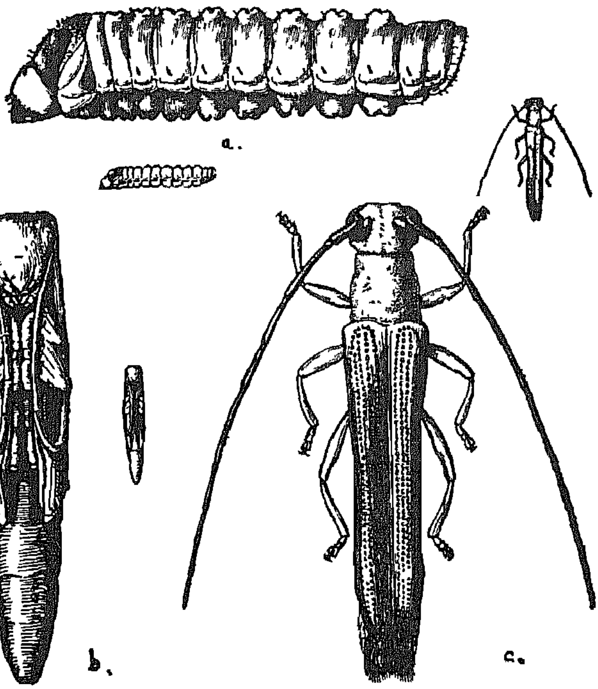


Fig. 63. Larva, pupa and beetle of *Oberea*; several species of *Oberea* are borers of living twigs and shoots of trees.

This species is primarily a borer of species of *Ficus* breeding in the dead wood, but also attacking living branch and small wood; it is an occasional pest of cultivated fig. The beetles are active by day and feed by gnawing the green bark of shoots, or by eating holes in the blade of large leaves such as those of *Ficus religiosa*. The pupal chamber is illustrated in fig. 69. The exit-tunnel is as in *O. anogeissi*. In north India the life-cycle is annual with an extended emergence-period from May to November (May 20 percent, June 36 percent, July 21 percent, August 9 percent); a portion of the brood may be prolonged to the second year but if the wood dries out considerably these belated individuals do not survive. The larva and pupa are described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, pp. 56, 57, figs. 60, 61.

Olenecamptus indianus in *Anogeissus acuminata*, *A. latifolia* *Lagerstroemia calyculata*, *Phyllanthus emblica*, *Randia dumetorum*, *Terminalia belerica*, *T. tomentosa*. India and Burma. Beetle, L, 17 mm., light or yellowish brown, with yellowish spots and flecks on the elytra [fig. 49, No. 4]. The life-cycle of this sapwood borer is annual in north India with emergence in May–August (50 percent in June, 44 percent in July).

Olenecamptus pseudostrigosus in *Terminalia myriocarpa.* Beetle, L, 17 mm., reddish-brown with yellow spots and flecks on the elytra; the life-cycle is annual.

Olenecamptus salweeni in *Anogeissus acuminata, A. latifolia, Terminalia pyrifolia.* Beetle, L, 17 mm., resembles *O. indianus* in colour and markings. Emergence occurs in May–July, mainly May and the life-cycle is annual with prolongation into the second year.

Olenecamptus signaticollis in *Lagerstroemia flos-reginae, L. lanceolata.* Beetle, L, 15 mm., greyish-brown with large white spots on prothorax and elytra. There are probably two generations per annum in south India with prolongation to the second year.

Pachydissus birmanicus in *Xylia dolabriformis.* Beetle, C, 1½ inches, dark brown with yellowish pubescence. This species attacks large living trees over 2 feet 6 inches in girth. The larva feeds on the sapwood under the bark over an area of about a square foot around the mouth of its gallery; the mature gallery is large, running into the heartwood radially for 3 or 4 inches and then axially downwards for 5 or 6 inches with a diameter of about 1 inch. The attack occurs up to 40 feet from the ground. The pupal chamber is closed by a simple cap-shaped operculum. Emergence occurs in October mainly, but also in April and the life-cycle may be prolonged for two years. Where it is common *P. birmanicus* causes as much damage to *X. dolabriformis* as does the beehole borer to teak in heavily beeholed localities. Nearly half the sleepers may be rejected on account of worminess due to *Pachydissus.*

Garthwaite P.F., 1940, *A guide to the borers of commercial timber in Burma*, pl. ii, figs. 1, 2.

Pachydissus xyliae also attacks *Xylia dolabriformis* in Burma.

Palimna annulata in *Lannea grandis, Melanorrhoea usitata, Spondias mangifera.* Beetle, L, 1 inch, ashy-grey, to brownish-grey, with very variable patterning of black to grey interlaced streaks or spots (varieties *mouhoti* Pascoe, *nebulosa* Breuning, *tessellata* Pascoe). Widely distributed. Emergence occurs in May, June; the adult is also on the wing in December and there are probably two generations a year in Assam, Bengal. The larval tunnels extend deeply into the heart of the log.

Palimna palimnoides in *Pentacme suavis.*

Paradihammus sericeus in *Aesculus punduana.* Beetle, L, 15 mm., greyish-brown. Emergence occurs in April–August, mainly May.

Paraleprodera insidiosa in *Bauhinia vahlii.* Beetle, L, 5-10 mm., light brown, elytra each with a dark brown postmedian spot. Emergence occurs in April and also August, September from dry climbers.

Paraleprodera stephana in *Juglans regia.*

Paramimistena polyalthiae in *Polyalthia simiarum.*

Paranephelotes laosensis in *Dalbergia latifolia, Millettia*

pendula. Beetle, 13 mm., speckled grey and dark brown with a dark postmedian band on the elytra. Beetles occur in May–July.

Parapalimna ducalis in *Celtis australis.*

Paripocregyes fuscovittatus in *Terminalia belerica.*

Paripocregyes terminaliae in *Terminalia belerica.*

Perissus bauhiniae in *Bauhinia vahlii, Buchanania latifolia.* Beetle, L, 6-10 mm., black, elytra with 4 white bands. The life-cycle in thicker woody stems of the climber is annual with emergence in June–September (July 40 percent, August 50 percent).

Perissus dalbergiae in *Dalbergia sissoo,* in the Punjab and United Provinces. Beetle, C, 7-11 mm., dark brown with dense dark grey pubescence and 2 darker spots on the pronotum, and lighter grey or fawn curved markings on the elytra [fig. 64].

The eggs of this bark and sapwood borer are laid on the bark of recently dead trees, but under certain conditions living trees may be affected. Shisham trees that are weakened by root-disease due to *Ganoderma lucidum* or *Fusarium,* or when growing on unsuitable soil and repeatedly defoliated by *Plecoptera reflexa* (Noctuidae) are attacked. The site of attack on living bark is recognisable by the outpouring of a black gummy fluid which runs down the trunk. (Black gum is similarly produced from wounds or borings by *Sinoxylon* beetles). The larval tunnels lie in the bast and sapwood and are tightly packed with dust and they are invaded by the black gum. Pupation takes place at a depth of about half an inch. The exit-hole of the beetle is nearly a fifth of an inch wide. The life-cycle may be completed in one year with an emergence period extending from April–October (July 34 percent, August 39 percent, September 13 percent). In dry wood the larva continues its development for two to four years. The larva is described by Gardner, 1931, *Ind. For. Rec.*, XVI, iii, p. 174. Control measures for outbreaks in shisham plantations are given in *Ind. For. Rec.*, Ent. IV, i, Guide to insects of *Dalbergia sissoo,* p. 31; see also Part Two.

Perissus laetus in *Acacia catechu, Albizzia odoratissima, A. stipulata, Cassia fistula, Dalbergia fusca, Dolichandrone rheedii, Derris elliptica, Ficus obtusifolia, Millettia brandisiana, Pyrus communis, Quercus serrata, Xylia dolabriformis.* Beetle, C, 8-11 mm., black, pronotum with 2 black spots or a single transverse band, elytra with grey curved markings. Assam to Thailand. Emergence occurs in May and September.

Perissus mutabilis in *Bauhinia retusa, Butea frondosa, Dalbergia fusca, Engelhardtia colebrookiana, Garuga pinnata, Mallotus philippinensis, Shorea robusta.* United Provinces to Thailand. Beetle, C, 8-13 mm., head and thorax ferrugineous-red to black, elytra black with ashy curved markings Emergence of this sapwood borer occurs in June, July, mainly June.

Perissus parvulus in *Cupressus lawsoniana, Pinus patula* in Ceylon. Beetle, C, 5-8 mm., dark brown to reddish-brown, elytra

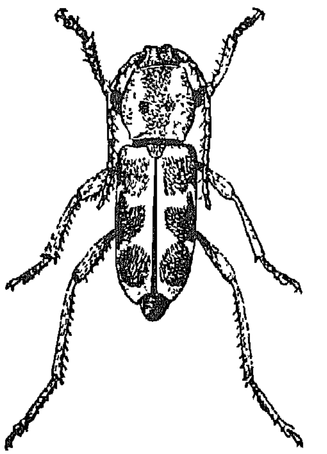


Fig. 64. Beetle of *Perissus dalbergiae*, natural size 9 mm.

ferrugineous at the base and with 2 narrow yellow bands. Emergence occurs in April–June.

Perissus quercus in *Quercus incana.*

Pharsalia proxima in *Mangifera indica, Terminalia belerica.* Indian Peninsula and Ceylon. Beetle, L, 1 inch, elytra variegated with yellowish to dark brown, base dark brown, scutellum and pronotum yellowish-brown (var. *intermedia* Heller). The life-cycle is annual with emergence in September, October.

Pharsalia suturalis in *Acrocarpus fraxinifolius, Elaeocarpus* sp. in Assam, Bengal. Beetle, L, 19 mm., black, prothorax and elytra speckled with orange, brown and black. Emergence occurs in May.

Plocaederus ferrugineus in *Bombax malabaricum, Boswellia serrata, Buchanania latifolia, Diospyros melanoxylon, Hardwickia binata, Lannea grandis.* Beetle, C, 1 to 1 3/4rs of a inch, reddish-brown, head and thorax dark brown or almost black. Peninsula and Ceylon. The larval galleries in the sapwood are broad and straggling, deepest in the middle and shallowing out at the sides, and packed with fibrous dust. For pupation the excavation is continued inwards to the heartwood and the chamber so formed is packed with short wood-fibres ; in this nest the larva prepares a flattened oval egg-like cell of calcium carbonate (one cocoon measured 2 1/8 inches—larger than any of the *Plocaederus obesus* cocoons). The distal end of this chalk cell may be level with the surface of the sapwood and becomes exposed if the bark and dust fall away. The emergence-period is April–July, mainly May ; beetles occur in the cells as early as November.

Plocaederus obesus

Bombax malabaricum, Buchanania latifolia, Butea frondosa, Caryota urens, Cedrela toona, Cordia myxa, Eriodendron anfractuosum, Garuga pinnata, Gmelina arborea, Kydia calycina, Lannea grandis, Mangifera indica, Protium serratum, Shorea robusta, Spondias mangifera, Sterculia colorata, S. urens, S. villosa, Terminalia tomentosa.

Beetle, C, 9/10ths to 1 3/5ths of an inch, chestnut-brown with a greyish pubescence, [fig. 61, No. 3]. Widely distributed in Indo-Malayan area.

Life-history: This species is a heartwood borer chiefly of soft woods. Living trees are not attacked except in the case of

Sterculia urens which is blazed and tapped for gum in the Central Provinces. The wounded bark and wood are bored by the larva. *P. obesus* is on the wing early in the year, first appearing in March in the plains of north India. The larvae rapidly penetrate into the deeper layers of the wood and tunnel very irregularly; some mature as early as August and others not until February largely owing to competition among themselves for the moister parts of the wood. The full grown larva is three inches long and the excavations in which it pupates are very wide galleries sometimes six inches deep from the surface. The terminal portion is filled rather loosely with long coarse fibres which are compressed and woven in the centre to form a small egg shaped cell in which the larva has sufficient room to lie only in a coiled position. The space is then lined with a shell of calcium carbonate nearly one-sixteenth of an inch thick, and during the excretion of this material the larva shrinks very considerably, so that its length is finally reduced to that of the long axis of the cell, i.e., about 1½ inches. This calcareous cocoon is quite regular and unlined with any other secretion. It is not fragile and withstands strong compression and is easily loosened from its nest of fibres. It resembles a large tortoise's egg [fig. 61]. The larva pupates as early as September or as late as next spring and shortly afterwards turns into a beetle and may emerge in October–December. The majority, however, hibernate as immature beetles in the cocoons, and normally emerge in March, April.

The egg, larva and pupa are described and figured by Gardner, 1925, *Ind. For. Rec.*, XII, ii, pp. 98-100, pl. ii, figs. 8-12; the cocoon is figured by Beeson, 1919, *For. Bull.*, 38, p. 4, pl. 1, fig. 7.

Plocaederus pedestris in *Mangifera indica*. Beetle, C, 1 inch, reddish-brown to blackish, with a pale grey pubescence, legs ferrugineous. The larva feeds between the bark and sapwood and later makes a wide oblique chamber-like tunnel into the heart of the wood, and in it forms a yellowish-white cocoon of calcium carbonate in which it pupates. Emergence occurs in June.

Pothyne acaciae in *Acacia gageana*. The larva is described by Gardner, 1931, *Ind. For. Rec.*, XVI, p. 191.

Pothyne combreti, 8-15 mm., *Combretum decandrum*. The larva is described in 1931, *tit. cit.*, p. 191.

Pothyne convexifrons, 14-16 mm., *Saccharum spontaneum*. The larva is described by Gardner, 1930, *Ind. For. Rec.*, XVI, vii, p. 161.

Pothyne moringae, 10 mm., in *Gmelina arborea*.

Prionomma atratum in *Boswellia serrata*. Beetle, C, 1 to 1½ inches, black or dark brown.

Prionus corpulentus in *Abies pindrow*, *A. webbiana*, *Juglans regia*, *Pinus excelsa*. Beetle, C, 1 1/3rd to 1 4/5ths of an inch, pitchy brown. The adult occurs in June–July. It is a borer of stumps and decaying logs making very large tunnels, the mature

larva being over five inches long. The larva is described by Gardner, 1927, *Ind. For. Rec.*, XII, ii, pp. 32, 33.

Pseudohaplothrix rivulosus in *Strobilanthes* sp. in Burma.

Pseudophilus testaceus in *Phoenix dactylifera.* Beetle, C, 1 to 1¼ inches, testaceous-brown, thorax and base of elytra reddish. Introduced to the Punjab from Iraq in imported date palm suckers about 1927; apparently not established in India.

Pterolophia andamanica in *Albizzia lucida, Enterolobium saman.*

Pterolophia bambusae in *Bambusa polymorpha.*

Pterolophia blairiella in *Albizzia odoratissima.*

Pterolophia dalbergiae in *Acacia gageana, Albizzia lebbek, Dalbergia sissoo.* Beetle, L, 8 mm., brown variegated with greyish and darker brown, elytron with a greyish-brown transverse angulate band, apex greyish. Emergence occurs in June-August.

Pterolophia densefasciculata in *Derris robusta, Milletia* sp.

Pterolophia gardneri in *Acacia gageana, Bauhinia vahlii, Dalbergia latifolia, Lannea grandis, Mallotus philippinensis, Morus indica.*

Beetle, L, 8 mm., brown to dark brown, variegated with greyish-brown spots and lines. The life-cycle in dry cut climbers and small stems is usually prolonged for more than a year up to three years. Emergence occurs in practically all months but mainly in June and September.

Pterolophia gardneriana in *Enterolobium saman.*

Pterolophia gerardiniae in *Albizzia* sp., *Butea frondosa, Euphorbia pulcherrima, Girardinia heterophylla, Hibiscus mutabilis, Lannea grandis.*

Pterolophia granulosa in *Juglans regia.*

Pterolophia griseofasciata in *Acacia* sp., *Albizzia lebbek, Vitis araneosa.*

Pterolophia infirmior in *Artocarpus integrifolia.*

Pterolophia maculata in *Michelia champaca.*

Pterolophia marmorata in *Michelia champaca.*

Pterolophia obscurioides in *Acrocarpus fraxinifolius, Cedrela toona, Juglans regia, Sapium eugeniaefolium.*

Pterolophia occidentalis in *Acacia* sp.. *Acrocarpus fraxinifolius, Artocarpus hirsuta, Bauhinia vahlii, Cudrania javanensis, Dalbergia paniculata, Engelhardtia colebrookiana, Ficus religiosa, Lagerstroemia parviflora, Lannea grandis, Mallotus philippinensis, Mangifera indica, Millettia auriculata, Myristica attenuata, Pterocarpus marsupium, Spatholobus roxburghii, Terminalia paniculata, Vitis araneosa, Wistaria* sp.

Beetle, L, 10-12 mm., greyish-brown, elytra at base with a semicircular black stripe from shoulder to shoulder, in apical third with a curved black stripe. The larval tunnels in thin barked stems groove the sapwood and the pupal chamber is also on the

sapwood surface. The life-cycle is annual but may be prolonged to the second or third year in dry stems and climbers; emergence occurs in nearly every month of the year but mainly in June, July (June 21 percent, July 56 percent, August 11 percent).

Pterolophia oculata in *Vitis latifolia*.

Pterolophia pallidifrons in *Mimusops littoralis, Sterculia alata*.

Pterolophia persimilis in *Acacia gageana, Clerodendron infortunatum, Croton tiglium, Dalbergia latifolia, Flemingia stricta, Girardinia heterophylla, Indigofera tinctoria, Lannea grandis, Michelia champaca, Morus indica, Ougeinia dalbergioides, Prunus* sp., *Tectona grandis, Tephrosia candida*.

Beetle, L, 8 mm., speckled chocolate, yellow and white, elytron with a large dorsolateral white spot or band behind middle. United Provinces to Hong Kong. Emergence from dry stems occurs in May-October, with an annual life-cycle.

Pterolophia rosacea in *Juglans regia*.

Pterolophia sterculiae in *Sterculia alata*.

Pterolophia tibialis in *Acrocarpus fraxinifolius*.

Pterolophia transversefasciata in *Albizzia lebbek, Gluta travancorica, Millettia auriculata, Shorea robusta, Tectona grandis, Terminalia myriocarpa*.

Pterolophia transverseplagiata in *Acacia gageana, Acrocarpus fraxinifolius, Bauhinia vahlii, Cryptolepis buchanani, Lannea grandis, Mallotus philippinensis, Ougeinia dalbergioides, Pinus longifolia*.

Beetle, L, 6 mm., variegated with brown and white, elytra with a broad white patch in the middle half produced to the suture posteriorly. Emergence occurs in April–July and September.

Pterolophia tuberculata in *Tectona grandis*.

Purpuriscenus indus in *Populus ciliata*.

Purpuricenus montanus in *Pinus excelsa, Quercus dilatata*. Beele, C, 10–16 mm., variable, black, entirely or black with outer margins of elytra red, or elytra red with sutural band black, prothorax with a red lateral spot or band. The adult occurs in April, May; the life-cycle is annual in branchwood or sapwood.

Purpuricenus sanguinolentus in *Acacia arabica, Dendrocalamus strictus*. Beetle, C, 12–20 mm., prothorax black, elytra orange with broad transverse median and apical black bands. The adult occurs in April–July and December. It has been bred from dry bamboo and has been observed gnawing living shoots of *Santalum album*.

Quettania coeruleipennis in *Prunus armeniaca, P. amygdalis, P. avium*.

Beetle, C, 21 mm., dark metallic blue. The adult emerges in May; the larva is a borer of the branches of living apricot trees in Baluchistan. The egg and larva are described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, pp. 45, 46, figs. 36 *a, b*, under the name "an unidentified larva (Callichromini)".

Remphan hopei in *Dipterocarpus turbinatus.* Burma to Borneo.

Beetle, C, 1½ to 4 inches, reddish-brown, smooth. [fig. 4, No. 5: fig. 67, No. 2]. This prionine is a heartwood borer of large logs. The mature larva reaches a length of 4½ inches and a width of one inch. The galleries of the borer are separate but very closely crowded and run transversely through the heartwood. Compared with the size of the tunnels of other timber borers those of *R. hopei* are enormous; the cross-section of the tunnel is 2 3/4 to 4 1/4 inches wide by 5/8ths to 1 inch deep; i.e., large enough to admit at once all the fingers of one's hand. They are loosely packed with coarse fibres. See fig. 67 showing larval tunnels in section. The beetle appears to mature at any time of the year in the Andamans. The egg, larva and pupa are described and figured by Beeson, 1919, *Ind. For. Rec.*, VII, v, pp. 12–15, pl. ii.

Rhaphipodus gahani in *Sapium sebiferum.* Beetle, C, 2 inches, prothorax and underside black, elytra glossy dark chestnut. [fig. 67, No. 1]. The adult occurs in August. The larval tunnel with its packing of coarse wood-dust and the pupal chamber are shown in longitudinal-section in fig 67.

Rhaphuma acrocarpi in *Acrocarpus fraxinifolius.*

Rhaphuma bimaculata in *Dalbergia sissoo.*

Rhaphuma desaii in *Castanopsis argyrophylla.*

Rhaphuma horsfieldi in *Albizzia odoratissima, Dolichandrone rheedii, Litsaea elongata, Juglans regia, Quercus* sp.

Beetle, C, 10–15 mm., elongate, with dense yellow pubescence, prothorax with 2 longitudinal dark stripes, elytra with 2 narrow longitudinal bands. Emergence occurs in April, May.

Rhaphuma maculata, 10 mm., in *Acacia leucophlaea, Bauhinia vahlii.*

Rhaphuma rhea, 10 mm., in *Dodonaea viscosa.*

Rhodopis alboplagiata in *Machilus odoratissima.* Beetle, L, 17 mm., speckled brown, elytra with patches of greyish and yellowish-brown, prothorax with 3 longitudinal yellowish-brown streaks. Emergence occurs in September. The larva is described by Gardner, 1931, *Ind. For. Rec.*, XVI, iii, p. 201.

Rhytidodera bowringi in *Mangifera indica.* Beetle, C, 9/10ths to 1 1/10th of an inch, reddish-brown, elytra with short, linear, yellowish spots. Eggs are laid on living shoots and branches of mango trees of over 8–10 years old and the larva bores down the centre of the branch making a tunnel that is kept clean of wood-dust. Frass and sap are ejected through holes. The life-cycle is annual and the beetles emerge in May–July. Usually the thicker branches of older trees are attacked; the bored branches bear green foliage for some time but eventually die back. The stages and damage are figured by T. B. Fletcher, 1930, *Rep. Imp. Ent.*, Pusa, 1928–29, p. 70, pl. ii, figs. 1–4. The larva is described by Gardner, 1932, *Ind. For. Rec.*, XVI, iii, pp. 168, 169.

Rhytidodera robusta in *Shorea robusta.* Beetle, C, 1¼ inch long.

Rondibilis plagiata, 12 mm., in *Clerodendron infortunatum.*

Ropica affinis, 15 mm., in *Acrocarpus fraxinifolius.*

Ropica basicristata, 9 mm., in *Millettia* sp.

Ropica fusconigrita, 6 mm., in *Acrocarpus fraxinifolius.*

Ropica granuliscapa, 8 mm., in *Albizzia lucida.*

Ropica praeusta, 8 mm., in *Calotropis procera.*

Ropica pseudosignata, 6 mm., in *Hibiscus tiliaceus.*

Ropica rufescens in *Bombax malabaricum, Cryptolepis buchanani, Cudrania javanensis, Euphorbia pulcherrima, Ficus glomerata, F. hispida, Jatropha curcas, Lannea grandis, Luffa aegyptiaca, Mallotus philippinensis, Mezenga zanthoxylum, Millettia auriculata, Ougeinia dalbergioides, Pongamia glabra.*

Beetle, L, 8 mm., reddish-brown to very dark brown variegated with greyish-yellow, elytra with a pair of wavy transverse white bands behind the middle. The life-cycle is annual with emergence in April–October. In the case of material originating from the Andamans 87 percent of the population emerged in May.

Ropica signata, 6 mm., in *Vitis araneosa.*

Ropica signatoides, 5 mm., in *Bauhinia vahlii.*

Rosalia hariola, 1 to 1 2/5ths of an inch, in *Evodia fraxinifolia, Mallotus roxburghianus.*

The larva is described by Gardner, 1932, *Ind. For. Rec.*, XVI, iii, pp. 169, 170.

Rosalia lateritia in *Quercus dilatata, Q. semecarpifolia.* Beetle, C, 1 to 1¼r of an inch, red above, black beneath, head black with 2 red spots, elytra frequently with small spots or bands. The adult occurs in May–September.

Sarmydus antennatus, C, 1 inch, in *Cryptomeria japonica.*

Sarmydus subcoriaceus, 20 mm., in *Pieris ovalifolia, Quercus incana.*

Sarothrocera lowi in *Engelhardtia spicata, Stereospermum suaveolens.* Beetle, L, 1 4/5ths of an inch, light brown to brown, base of elytra darker, antenna fringed on one side with black hairs. Emergence occurs in May–July. The larva is described by Gardner, 1932, *Ind. For. Rec.*, XVI, iii, pp. 180, 181, figs. 29, 30.

Serixia andamanica, L, 8–10 mm., in *Myristica andamanica.* The larva is described in 1932, *tit. cit.*, p. 196.

Serixia vateriae, 8 mm., in *Vateria indica.*

Smermus mniszechi, L, 20 mm., in *Laportea terminalis.*

Sthenias grisator.

Beaumontia grandiflora, Bougainvillea sp., *Chloroxylon swietenia, Croton* sp., *Erythrina indica, E. lithosperma, Manihot utilissima, Moringa* sp., *Morus alba, Nerium odorum, Rosa,* sp., *Tabernaemontana alba, Vitis vinifera, Wrightia tinctoria.*

Beetle, L, 24 mm., greyish-brown with white and brown irregu-

lar markings (resembling bark colouration), elytra with an elliptical greyish median spot, and an eye-shaped patch in the apical third. India and Ceylon.

The beetle girdles the living shoots of trees and woody climbers gnawing deeply into wood so that the shoot is killed and ultimately breaks off. In the girdled shoots and stems the beetle bites a slit in the bark and an egg is thrust in between the bast and the sapwood. The larva hatches in a week to 10 days and tunnels up and down the shoot completely reducing material of small dimensions to dust enclosed in a thin skin of bark; a certain amount of dust is ejected. Pupation occurs in an elongate chamber and the beetle escapes by a circular exit-hole. Emergence occurs in most months of the year but mainly in July, August. The rate of development varies considerably with the dryness and nutritive value of the food and the competition in crowded infestation. It is possible for the life-cycle to be completed in five months or to require more than a year. *S. grisator* is a pest of ornamental climbers, grape vines and flowering shrubs, also of mulberry plants. The larva is described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, pp. 55, 56, figs. 58, 59.

Stromatium barbatum.

Economic importance: This species is chiefly important as a pest of packing cases and the dimensioned timber used in their manufacture. It is also a common pest of furniture and woodwork in houses, shelves, door and window frames, rafters, panels, plywood, etc., and of wooden specimens in museums, wooden tentpins in military stores. Furniture and woodwork in buildings may be in use for several years before giving evidence of damage by *S. barbatum* in the form of ejected dust, noise of larval activity, exit-holes, breakage, etc. In the majority of cases the delayed appearance of damage is due to the long larval life, the timber having been attacked before manufacture or utilisation in the building. New attack on seasoned timber in buildings is usually an indication of neglect of a previously introduced infestation.

In the forest *S. barbatum* occasionally breeds in dry wood, e.g., the dead crowns of stagheaded trees. Reports of attack on green living trees have not been substantiated.

About 350 different kinds of wood are attacked by this species (for list see Beeson and Bhatia, 1939, *Ind. For. Rec.*, Ent., v, No. 1, pp. 174–176). It is found throughout India, Burma and Ceylon and also in Mauritius and Madagascar; it was introduced into England in tea-chests from India.

Life-history: Beetle, C, 1/2 to 1 1/6th of an inch, reddish-brown to almost black covered with a tawny pubescence, closely punctured, the elytra weakly costate. [fig. 4, No. 2: fig. 69,

No. 1] Beetles are inactive during daylight, hiding in dark shelters, and avoiding light if disturbed.

Longevity: The longest life in captivity at Dehra Dun was 32 days for the male, and 18 days for the female, the mode being 9 days for both sexes. The length of life of beetles kept in saturated atmosphere was about 1·3 days; the longer lives were attained in dryer atmosphere of 60 to 80 percent relative humidity.

Mating and oviposition: The newly emerged female has the ovaries mature and filled with fully developed eggs and mates as early as the first day after emergence. Mating takes place at night; there is no response on the part of either sex to the presence of the other sex during daylight unless they come actually and accidentally into contact. Egg-laying begins immediately after the first mating (if on a suitable wood surface) and is interrupted frequently for further mating. Eggs are deposited in small holes, crevices or fissures in wood, either singly or in groups of 2 to 5 crowded together away from light. The extrusion of the egg takes about 25 seconds; 4 or 5 may be laid in 2 minutes. The maximum number of eggs laid by a single female in captivity was 246; the mode is between 60 and 100 and the average about 100. The longest recorded oviposition period is 16 days, the mode about 7 days. In saturated atmosphere none or very few eggs are laid.

Site of oviposition: Completely smooth surfaces are avoided; varnishing a surface prevents oviposition if all holes and fissures are filled up. Where a wooden surface comes into contact with another surface and forms an angle, eggs are laid. Fissures formed by imperfect carpentry joints, rough surface with loose fibres, sawtooth-marks, etc., and any type of hole or overshadowed depression into which the ovipositor can be inserted are preferred. Oiling the surface of the wood does not prevent oviposition after the lapse of a few days if the wood has a rough surface; saturating the surface with solutions of napthalene in benzene and zinc chloride in water has no lasting deterrent effect.

Incubation-period: The incubation of the egg in June, July requires from 5 to 13 days; the mode is 10 days.

Larval habits: The egg and larva are described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, pp. 40, 41, figs. 5, 10, 12, 26, 30, 34. The egg is 2·0 to 2·5 mm. long and 0·8 mm. wide, elongate-ovoid, one end with a slight blunt thickening and the other end with a more distinct blunt prominence. The blunter end is extruded first and the egg so orientated is pushed into the oviposition-hole; from this end the larva emerges by cutting off a conical cap [fig. 65]. Apparently no part of the egg-shell is normally eaten by the larva. The first instar larva easily bores into almost any kind of wood, and through varnish, resin or oiled or otherwise antiseptically treated surfaces.

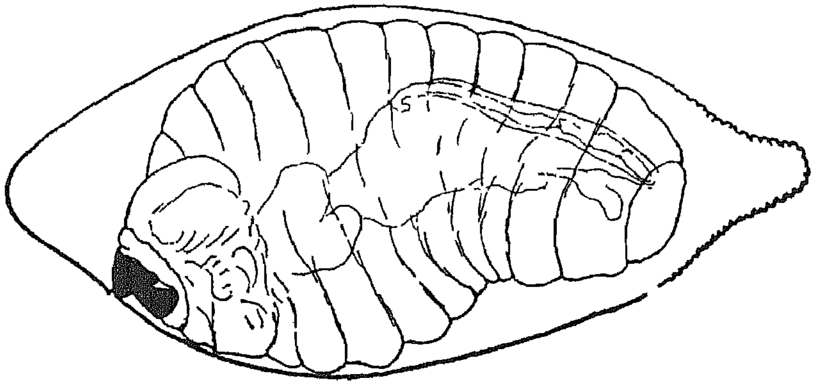


Fig. 65. Egg of *Stromatium barbatum*, showing larva just about to hatch.

The larval tunnels of *S. barbatum* are tightly packed with a very fine floury dust, much like that of Bostrychidae. They run irregularly in the depth of the wood without indication of pattern or uniform dimensions even when there is ample space and little competition. [fig. 69, No. 1] In crowded infestations they cross and interlace frequently until practically the whole of the interior of the wood except very hard zones is reduced to powder; the external surfaces are left nearly intact as paper-thin sheets. Dust is not ejected except through holes or cracks accidentally formed. *S. barbatum* works in large logs with the bark on as well as in thin planks and battens or sheets of plywood not more than 4 mm. thick. The sound produced by the scraping action of the mandibles of the larva is quite audible: in attacked furniture or woodwork in houses it is particularly noticeable.

The mature larva is about 1½ inches long. No special chamber or tunnel is prepared for pupation which takes place at various depths from the surface usually in May. The pupal-period lasts two weeks; the hardening off of the immature beetle takes about three weeks. The beetle bores a separate tunnel to the surface and escapes through an oval or circular exit-hole.

Life-cycle: The life-cycle may be completed in one year or several years: the longest life-cycle recorded in our cages from known dates of infestation is ten years. Under normal conditions the brood originating from one batch of eggs develops with an annual rhythm, beetles maturing after one year, two years, three years and so on in June, July and at no other time; often a year or two years in succession may be missed. The following is a typical sequence of emergence of one brood :—

1st	2nd	3rd	4th	5th	6th	7th year.
1	28	42	23	4	1 5	0·5 percent.

The differential rate of development of individual larvae may be ascribed to variation in the nutritional value of the wood eaten by the individual; those individuals that happen to excavate their tunnels in the more nutritious zones of the wood become full grown earlier: those that work in less nutritious zones increase in size more slowly and if not full-fed in April or May must wait for a further twelve months before transforming; in the later stages of a crowded infestation the backward larvae are forced to work through the frass of earlier years from which most of the nourishment has been extracted and their development is consequently still more protracted.

Food: The essential constituents of the food of the larva of *S. barbatum* have not been isolated. It is apparently not so dependent on the presence of starch and soluble sugars as are, for example, Bostrychidae, but in some species of timber, particularly Leguminosae, only the sapwood is attacked and the heartwood is avoided; unpalatibility in the latter case may be due to absence of starch, presence of poisonous gums, resins, etc., or simply to hardness. It is probable that the gut of the larva contains the enzyme cellulase which enables it to digest cellulose, as does the larva of *Stromatium fulvum*.

Emergence-period: The beetles emerge during June and July, rarely also at the end of May. The percentage of the total population emerged by a given date varies from year to year.

The maximum and minimum possible emergences at intervals of five days during the emergence-periods recorded over many years at Dehra Dun are :—

Date	Gradient of quickest possible emergence.	Gradient of slowest recorded emergence.
June—1st	5 percent	0 percent
10th	10	0
15th	30	0
20th	52	0
25th	76	10
30th	96	20
July—5th	98	40
10th	100	57
15th	..	70
20th	..	82
25th	..	92
30th	..	99

The initial date and duration of the period of emergence of beetles in any one year is largely determined by the quantity of rain at the end of the dry season and beginning of the monsoon and the resulting atmospheric humidity. The humidity of the air determines the moisture-content of the wood and wood-dust in which the pupae and immature beetles of *S. barbatum* are resting. Increased humidity accelerates the development and emergence of

EMERGENCE PERIOD OF STROMATIUM BARBATUM

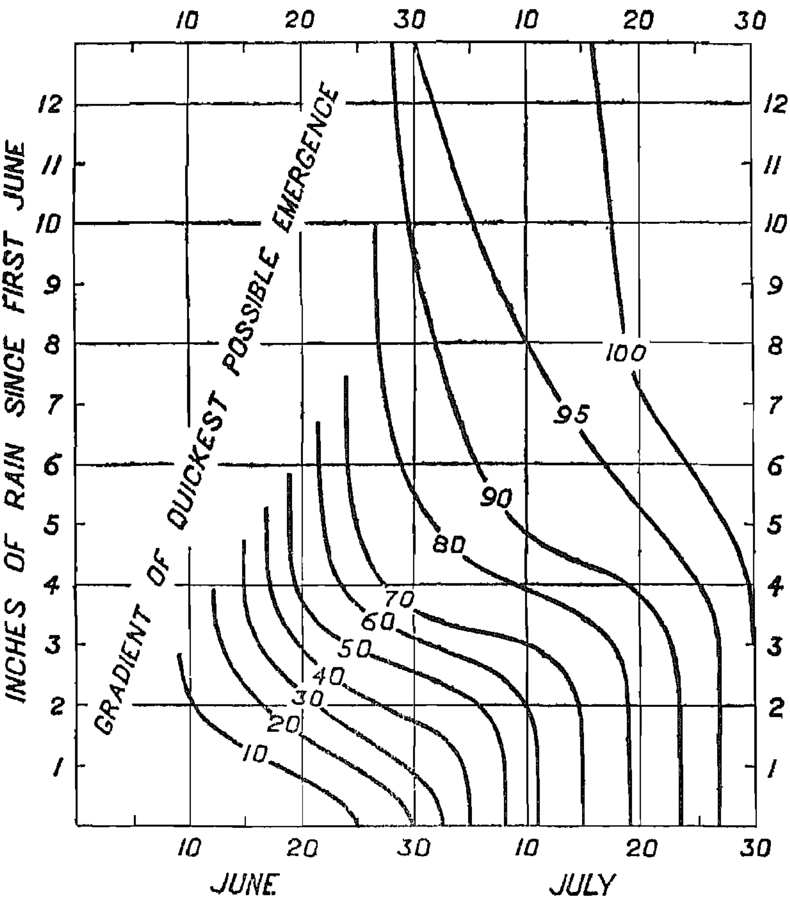


Fig. 66. Correlation of the number of inches of rain falling since June 1st, the date, and the percentage of the total annual population of beetles of *Stromatium barbatum* emerged. The zones of emergence-percent reach the quickest possible rate in the gradient on the left, and the slowest recorded rate in the gradient on the right. Thus, on June 30th if 10 inches of rain has fallen about 90 percent of the beetles will have emerged; if only 1 inch of rain has fallen about 30 percent of the beetles will have emerged. Compare with fig. 58.

the beetle. Hence, with early and abundant rainfall emergence begins early and is accelerated; with late or deficient rainfall emergence is delayed and protracted.

From the percentage of the annual population of beetles emerging during successive ten-day periods in June and July and the corresponding rainfall since June 1st. it is possible to construct a graphical representation of zones of emergence from which one can read off the percentage of the total annual population that may be expected to emerge on a given date with given quantity of rainfall. This is shown in fig. 66.

For further details see Beeson and Bhatia B. M., 1939, *Ind. For. Rec.*, Ent., v, No. 1, pp. 174–183.

For control measures see Part Two.

Stromatium longicorne in *Anogeissus acuminata*, *Cassia fistula*. Assam to Borneo. Beetle, 17–25 mm. Recorded as borer of furniture in Netherlands Indies.

Sybra ceylonensis, 7 mm., in fruits of *Calotropis procera*.

Sybra signatoides, 7 mm., in *Pinus patula* in Ceylon.

Teledapus dorcadioides in *Abies pindrow*, *Cedrus deodara*, *Picea morinda*. Beetle, C, 12–20 mm., reddish-brown to dark brown, apterous. The life-cycle is annual with emergence in April–June. The wood in which it occurs is rotten or beginning to decay.

Tetraglenes insignis in *Cryptolepis buchanani*. Widely distributed in the Oriental Region. Beetle, L, 15 mm., piceous with greyish-brown pubescence. A borer of dry climbers emerging in May–August. The larva is described by Gardner, 1931, *Ind. For. Rec.*, XVI, iii, p. 192, figs. 41, 49.

Tetraommatus filiformis in *Chloroxylon swietenia*. South India and Ceylon. Beetle, C, 5–10 mm., prothorax reddish-brown, elytra brownish to testaceous, antennae and legs yellow.

Tetraommatus insignis in *Myristica longifolia*. Assam to Malaya.

Tetraommatus ocularis continentalis in *Pinus longifolia*. Beetle, C, 5 mm., light brown. A borer of twigs and small branches emerging after one year in July–October, and sometimes carrying over to the second year. The larva is described by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, p. 38.

Tetropium oreinum.

Cedrus deodara, *Picea morinda*, *Pinus excelsa*. Beetle, C, 10–17 mm., dark brownish to black, the upperside for the most part dull. [fig. 4, No. 9].

Life-history: The beetle emerges in May, June and lays eggs on newly felled green or standing sickly trees, preferably deodar. The eggs are deposited singly in crevices on the sheltered sides of the trunk or log. The young larva bores into the inner

bast and cambial region forming shallow excavated patches which are continued later as long, irregularly curving, shallow tunnels, grooving bast and sapwood and filled with wood and bark-dust. After resting during the winter months the larvae resume tunnelling in the spring and from April onwards bore into the sapwood more or less horizontally for a half to one and a half inches to form an elongate oval pupal cell parallel with the axis of the log and wider in diameter than the connecting tunnel. In thick barked logs or in stumps the pupal chamber may lie in the bast or groove the sapwood superficially. The pupal period lasts probably a month or six weeks. The beetle escapes by the connecting tunnel and an exit-hole gnawed straight through the overlying bark; the life-cycle is annual with emergence in May–July. Logs brought from high elevations to say 2,000 feet may yield beetles in January–March. The larva and pupa are described in 1927, *Ind. For. Rec.*, XIII, pp. 35–36, fig. 9, 29.

Tetropium oreinum is definitely a secondary borer and, though requiring freshly killed bark in the early larval instars, is unable to establish itself in standing trees of which the vitality is high enough to withstand borers by production of resin in the initial tunnels. The vitality of a sickly tree varies in different parts of the trunk and branches and roots, and it is possible for *T. oreinum* to establish in one part and fail in another part of the same tree. The secondary borer fauna of deodar is determined by other factors which cause either the crown or the roots to die off first.

See Beeson and Bhatia B.M., 1939, *Ind. For. Rec.*, Ent., V, No. 1, pp. 185, 186, for synonomy.

Therippia affinis in *Acacia melanoxylon* in Ceylon. May.

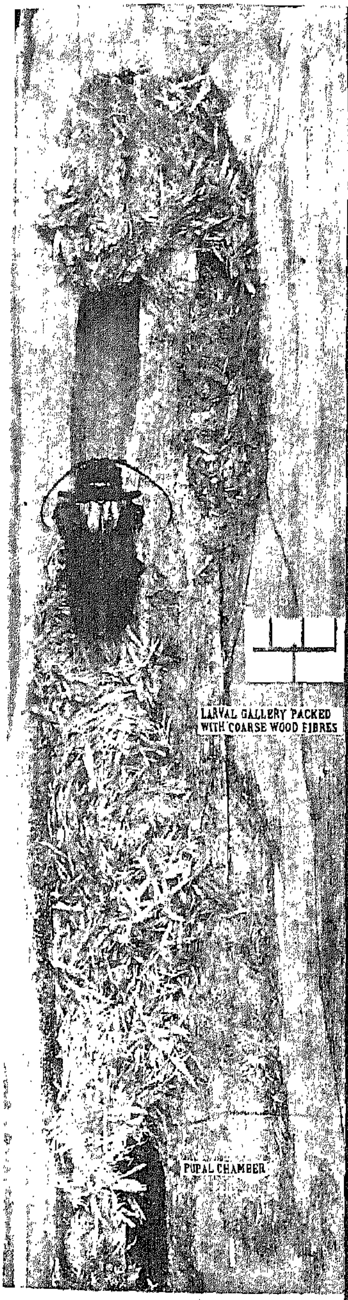
Thranius triplagiatus in *Litsea citrata*, *Machilus edulis* in Assam-Bengal. Beetle, C, 20 mm., head prothorax and body beneath fulvous, antennae black, elytra fulvous, each with the greater portion of the apical half, a transverse spot at the base, and a large rectangular spot at the side a little behind the base, black. The larva is described by Gardner, 1931, *Ind. For. Rec.*,

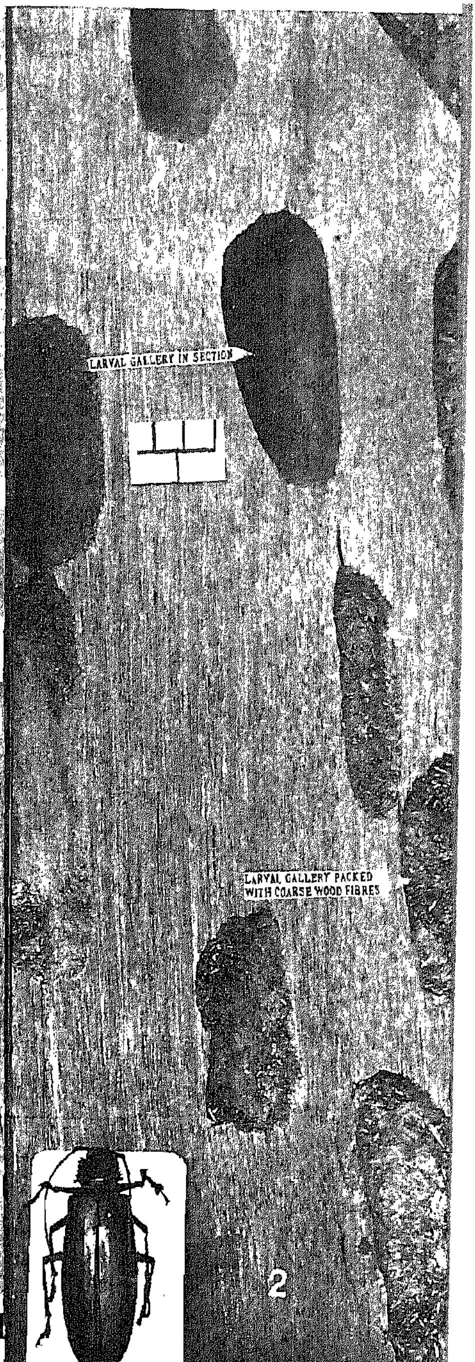
Fig. 67. Damage to wood by Cerambycidae

No. 1. *Rhaphipodus gahani*—Longitudinal section through wood of *Sapium sebiferum* showing larval tunnels and pupal chambers and beetle of *R. gahani;* the larval tunnel is packed with very coarse wood-fibres ; the pupal chamber is empty.

No. 2. *Remphan hopei*—Tangential face of a plank of *Dipterocarpus turbinatus* showing larval tunnels and beetle of *R. hopei* ; the larval tunnels appear in almost transverse section and are normally packed with coarse wood-fibres ; these tunnels are larger in dimension than the tunnels of any other Indian Cerambycidae.

Both photographs are on the same scale, about half natural size as indicated by the inch-centimetie scales.





SAPIUM SEBIFERUM

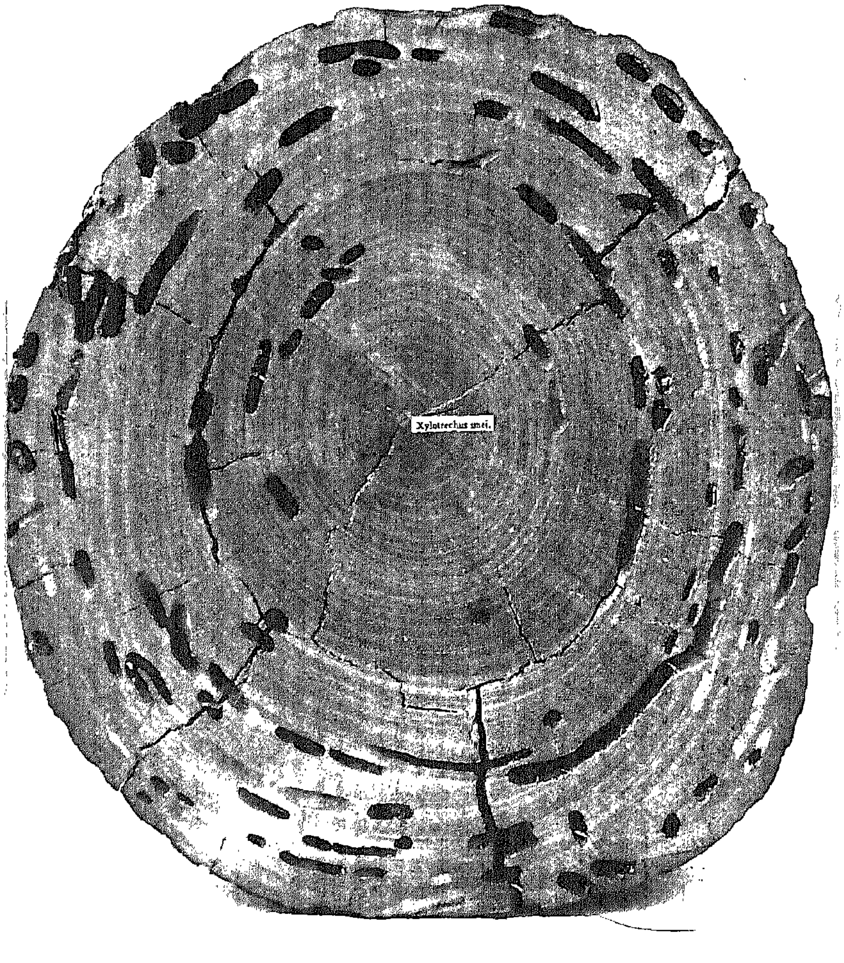


Fig. 68. Xylotrechus smei, CERAMBYCIDAE. Larval tunnels exposed on a cross-section of Schrebera swietenioides.

XVI, iii, pp. 171-172, figs. 12, 13. Emergence occurs in April, May (mainly April) and in August-January (mainly August). The life-cycle may vary from $\frac{1}{2}$—$1\frac{1}{2}$ years.

Thylactus simulans in *Bucklandia populnea*. Beetle, L, 1 3/10ths of an inch, prothorax dark brown with grey median streak, elytra greyish-brown with black longitudinal streaks basally, medially and apically.

Trichagnia fuscomaculata in *Terminalia paniculata* in south India.

Trinophylum cribratum in *Quercus dilatata, Quercus incana*. Beetle, C, 10-13 mm., chestnut-brown, more or less nitid, sparsely furnished above with short semi-erect fulvous brown hairs. This species is a sapwood borer of logs of oaks with an annual life-cycle, emerging in May, June. The pupal chamber is a relatively long narrow tunnel (2 inches) taken vertically down $\frac{1}{2}$ to $\frac{3}{4}$ is of an inch within the sapwood. See Beeson and Bhatia, 1939, *Ind. For. Rec*, Ent.. V, No. 1, p. 187 for synonomy.

Trirachys atkinsoni in *Pentacme suavis* in Burma. Beetle, L, 1 1/3 to 1 3/4 inches, resembles *Aeolesthes holosericea* in its colour-pattern and general appearance but prothorax is strongly and regularly wrinkled transversely and has a pair of spines. April.

Xenicotela distincta, L, 12 mm., in *Evodia fraxinifolia*.

Xenolea asiatica, L, 7 mm., in *Cudrania javanensis*.

Xenolea tomentosa, L, 8 mm., in *Pterocarpus dalbergioides*. Emergence occurs in May-September, mainly in July; the life-cycle may extend to two or three years.

Xoanodera regularis, C, 20 mm., in *Ficus elastica*. April.

Xylorhiza adusta in *Callicarpa arborea, Premna pyramidata*. Beetle, L, 1 3/10ths to 1 7/10ths of an inch, velvety, yellowish with longitudinal, contiguous, brown stripes; basal segment of antenna hairy. India to Malaya. Beetles eat the bark of shoots of *Premna* sp. and *Wrightia tinctoria* in May-September.

Xylotrechus basifuliginosus in *Picea morinda, Quercus semecarpifolia, Quercus* sp. Beetle, C, 15 mm., resembling *X. smei* in colour pattern.

Xylotrechus buqueti.

Acrocarpus fraxinifolius, Cedrela toona, Celtis australis, Cryptocarya wightiana, Gmelina arborea, Kydia calycina, Lagerstroemia parviflora, Mallotus philippinensis, Millettia pendula, Myristica longifolia, Pterocarpus dalbergioides, Shorea robusta, Tectona grandis. India to Java. Beetle, C, 6-12 mm., dark brown, with greyish or tawny-yellow pubescence with a black patch on the pronotum and three curved transverse bands on the elytra.

Eggs are laid in bark in groups of two to five from which the larval galleries radiate horizontally just grooving the inner bark or sometimes lying entirely in the sapwood. The larvae make very irregular tunnels which frequently cross each other; when very

crowded they are carried into the outer zones of the sapwood but maintain a direction more or less in the plane of a circumference. The packing is a fine dust of wood-particles with some bark. The pupal chamber is made at a depth of about half an inch and is not constant in shape or orientation, varying from vertical to radial. The beetle emerges by the most direct route, excavating a short horizontal tunnel that takes off from the upper end of the pupal chamber; the exit-hole is circular.

The life-cycle may be semi-annual or longer. Emergence occurs almost throughout the year but predominantly in March–June (April 20 percent, May 23 percent, June 20 percent). The emergence-period of one infestation may extend for five months. The larva is described in a key to the genus *Xylotrechus* in 1931, *Ind. For. Rec.*, XVI, iii, p. 172.

Xylotrechus carinifrons in *Chloroxylon swietenia*, *Eugenia* sp., *Tectona grandis* in Burma and Ceylon. Beetle, C, 8–15 mm., closely allied to *X. smei* and *X. subscutellatus* but the elytra light brown or reddish near the anterior, sutural band. Emergence in February–May.

Xylotrechus contortus in *Cedrela serrata*, *Juglans regia*, *Rhododendron arboreum*. Beetle, C, 12–15 mm., resembles *X. incurvatus*.

Xylotrechus incurvatus in *Prunus nepalensis*. Beetle, C, 10–15 mm., densely pubescent, luteous-yellow on the head, prothorax and elytra, yellowish-white on the body beneath, antennae and legs testaceous, fine spots on the prothorax and some narrow strongly curved bands on the elytra. The larva is described in 1931, *tit. cit.*, p. 172.

Xylotrechus magnicollis, C, 15 mm., in *Ficus elastica*, *Millettia brandisiana*, *Mimusops elengi*, *Quercus serrata* in north India and Burma. Life-cycle annual, prolonged to the second year. See Beeson and Bhatia B. M., 1939, *Ind. For. Rec.*, Ent., V, No. 1, p. 192 (as *renominatus* Beeson and *gahani* Stebbing).

Xylotrechus quadripes.

Coffea arabica, *Cudrania javanensis*, *Jasminum dispermum*, *Premna pyramidata*, *Rhus semiciliata*, *Tectona grandis*. India to Thailand. Beetle, C, 7–18 mm., black, thorax yellowish with 3 black spots, elytra with 3 yellowish or greenish chevrons of which the most anterior extends along the suture to the scutellum, elytral base bordered with an oblique line running inwards from the shoulders; the female is larger and stouter.

Life-history: The flight-season of the beetle in south India is October–December, and in Indo-China (Tonkin) is August–October; a weak emergence may take place in March–April. The beetles live for about three weeks and are active in bright hot weather, sluggish in cloudy moist weather. The female lays 50 to 80 eggs singly or in small groups in crevices or under scales of

bark. The eggs hatch in 6 to 9 days, or longer in cold weather and the larva bores below the bark into the wood. The larval period may be completed in 3 or 4 months but ordinarily requires 8 to 10 months before pupation. The pupal period lasts 3 or 4 weeks and the beetle emerges 3 to 7 days later. In living coffee trees the life-cycle is normally annual but in dead wood it may be completed twice in a year.

Economic importance: The species is the most serious pest of coffee in south India and is known as the Coffee Borer or White Borer. It is a regular pest of living arabica coffee bushes; robusta and liberia coffee are less liable to attack unless weakened by other causes. Young plants are killed by the borings of the larvae in the stems. The tunnel of one larva is sufficient to kill a five year old tree; older trees may survive the attack of several larvae. It is said to attack living *Ixora coccinea* and *Olea dioica*. In forest regions it occasionally breeds in dead poles and stumps of *Tectona grandis*.

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Xylotrechus smei.

Adina cordifolia, Aegle marmelos, Anogeissus latifolia, Bauhinia retusa, Bombax malabaricum, Bridelia retusa, Buchanania latifolia, Butea frondosa, Calycopteris floribunda, Careya arborea, Cassia fistula, Cedrela toona, Chloroxylon swietenia, Dalbergia latifolia, Dalbergia paniculata, Dalbergia sissoo, Ehretia acuminata, Eugenia jambolana, Ficus gibbosa, Ficus religiosa, Garuga pinnata, Gmelina arborea, Grewia tiliaefolia, Grewia vestita, Holoptelea integrifolia, Hymenodictyon excelsum, Kydia calycina, Litsaea sebifera, Machilus odoratissima, Mallotus philippinensis, Mangifera indica, Morus alba, Morus indica, Pterocarpus marsupium, Schrebera swietenioides, Shorea robusta, Strychnos nux-vomica, Tectona grandis, Terminalia tomentosa, Vangueria spinosa, Vitex altissima, Vitex pinnata, Vitis latifolia, Xylia dolabriformis.

Beetle, C, 10–18 mm., brown with a greyish or yellowish pubescence on head, prothorax and forming bands or spots on elytra; the colour of the markings varies from almost entirely yellow to grey, and the elytral pattern varies from an apical and basal band and 2 lateral spots, to an apical and a basal band connected to a post-median and an ante-median band and a humeral spot; the prothorax may be reddish. [fig. 4, No. 7].

Life-history.

This species is a common sapwood-borer characteristic of north, west and central India; it is less common in Assam, Bengal and south India-Ceylon where it is replaced by other species of *Xylotrechus*.

Oviposition: The maximum number of eggs laid by one female is 190 and the maximum laid in 24 hours is 60; the longest recorded oviposition-period is 6 days in April. Eggs are laid in crevices and covered depressions on the surface of bark in large clusters. The egg hatches in 4 or 5 days in April.

Larval period: The rate of larval development is very variable (see below, life-cycle and emergence-period). By inoculating newly hatched larvae in freshly cut logs (of *Shorea robusta*) between the 5th and 14th April the emergence of beetles was obtained as early as the 14th June. The shortest larval period under these conditions was 52 days in April, May, and the pupal period 18 or 19 days. Ripe eggs inoculated on 10th July gave rise to pupae on the 13th October, i.e., a larval life of about 93 days. The pupal period in October was 18-22 days. The larva is described and figured by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, pp. 46, 47, figs. 4, 20.

X. smei attacks newly felled trees within a month of felling and also several months after felling; girdled trees and the crowns of dying or stagheaded trees are attacked. Logs stored in the sun are more liable to be attacked than logs stored in the shade but the preference is not very strongly marked. The larval tunnels are excavated on the surfaces of the sapwood and inner bark, are flattened-oval in section and tightly packed with bark and wood-dust; in a crowded infestation the tunnels closely interlace. The pupal chamber is a cell about $\frac{3}{4}$ of an inch long formed at a short depth in the sapwood. In timbers that have a strongly differentiated heartwood the borings are confined to the sapwood, but in homogenous wood the tunnels may run right into the centre of the log and trend irregularly or are more or less concentric with the zones of growth. Fig. 68 shows a cross-section of *Schrebera swietenioides* with tunnels running in the annual rings. The beetle escapes by the prepupal tunnel and makes a circular exit-hole in the bark.

Life-cycle: Emergence of *X. smei* (in Dehra Dun) begins at the end of March from overwintered broods and is at its peak in May and may continue to the end of November. Eggs laid in April and May give rise to short-cycle and long-cycle generations, the former taking $2\frac{1}{2}$ to 7 months and emerging between the beginning of July and the end of November and the latter hibernating to emerge in the second year. Eggs laid at the beginning of July and later in the year do not produce a complete generation in the same year, as the immature beetle or larva passes the cold weather in a resting stage and the adult emerges in the second year between

April and November. The shortest life-cycle of overwintering broods is about 6 months, and the longest might be 16 months.

Emergence-period: The percentage of the population of the overwintered generation emerging monthly in the second year is: April 12 percent, May 41 percent, June 30 percent, July 5 percent, August to November 9 percent.

The average emergence-period from infestations of numerous species of trees at all seasons for the whole year for the Dehra Dun region as based on over 1,000 records is:—

Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
3	18	23	12	10	8	11	10	3 percent

From material originating from central and south India emergence occured progressively earlier:—

	April	May	June	July
Central Provinces, Rajpur ...	2	48	35	5 percent
Bombay, Thana ...	10	64	10	3
Madras, Nilambur ...	34	44	14	1

LITERATURE:

Beeson and Bhatia B. M., 1939, *Ind. For. Rec.*, Ent, v, No. 1, pp. 192-198, fig. 17.

Xylotrechus stebbingi in *Quercus dilatata.* Beetle, C, 12–18 mm., head and prothorax grey the latter with four small brown spots in a transverse row, elytra with small ashy marks in three interrupted bands.

A borer of the inner bark and sapwood of moru oak logs and stumps. The larval gallery winds irregularly and reaches a length of about 8 inches and a breadth of 1/8th of an inch; it terminates by a short connecting tunnel in a pupal chamber parallel to the long axis. The beetles emerge in June, July and the generation is annual.

Xylotrechus subcarinatus in *Acacia* sp., *Phoebe lanceolata, Maesa* sp., *Terminalia myriocarpa.* April, May.

Xylotrechus subdepressus in *Evodia fraxinifolia.* Beetle, C, 12–17 mm., densely covered with ochreous-yellow pubescence, varied above with dark brown spots and bands, elytra each with five dark brown spots. The larva is described in 1931, *Ind. For. Rec.*, XVI, iii, p. 173.

Xylotrechus subscutellatus in *Coffea arabica, Dalbergia latifolia, Kydia calycina, Pterocarpus marsupium, Tectona grandis, Vitex altissima, V. pinnata* in south India and Ceylon. Beetle, C, 10–17 mm., dark brown, with a tawny or greyish pubescence on the head and prothorax and forming four bands on the elytra.

A sapwood-borer of small wood, logs and standing dying trees. The larval tunnels may penetrate deep into the heart but return to near the surface for pupation. Emergence occurs throughout the year but mainly in April and in July, August The shortest life-cycle is probably annual but it may be prolonged for a second year. The Annual Reports on Forest Administration in Coorg record this

species as killing trees of *Dalbergia latifolia* and *Pterocarpus marsupium* in plantations, but there is no evidence that it is capable of primary attack on healthy trees.

Xystrocera festiva is a pest of *Albizzia* spp. used as shade trees in tea gardens in Burma, Malaya and Java. Its life-cycle and habits are similar to those of *X. globosa* in wetter climates.

Xystrocera globosa.

Acacia catechu, *Acacia modesta*, *Acrocarpus fraxinifolius*, *Albizzia lebbek*, *Albizzia lucida*, *Albizzia moluccana*, *Albizzia odoratissima*, *Albizzia procera*, *Albizzia stipulata*, *Bauhinia acuminata*, *Bombax malabaricum*, *Grewia tiliaefolia*, *Xylia dolabriformis*. Widespread in the Oriental Region and beyond. Beetle, C, 3/5ths to 1 1/3rd of an inch, reddish-brown, parts of prothorax metallic blue or green, elytra testaceous-yellow, each with a metallic blue or green longitudinal band. [fig. 69, No. 4].

Life-history: The larval tunnels run in the inner bark mainly but also groove the sapwood superficially. In trees with thick bark a heavy infestation reduces more than half the thickness of the bark to dust so that the bark readily separates from the wood. The prepupal tunnel is made at a right angle or an obtuse angle to the surface of the sapwood and then turns downwards or upwards to terminate in a pupal chamber parallel to the long axis of the log. This chamber is lined throughout with a fine deposit of calcium carbonate, very thin so that the inequalities and minor projections on its wall are hardly concealed; the lining is white with some yellowish discolouration especially at the lower end where the larval exuviae rest. The upper end is closed by a thin, smooth, ellipsoidal dome of calcium carbonate about 1/4th of an inch high and 7/16ths of an inch wide. The calcium carbonate is produced in two of the four Malpighian tubules. The pupal period lasts about three weeks. See fig. 69 for longitudinal section of log showing pupal chamber and exit-hole.

The digestive juice of the larva of *X. globosa* contains amylase, saccharase and maltase but does not contain cellulase and consequently it does not digest cellulose. There are no mycetocytes in any part of the body. The principal food-supply is from other carbohydrates and soluble sugars in the sapwood. The heartwood of *Albizzia lebbek* contains only small traces of starch and sugar and this fact explains why the larval tunnels do not penetrate the heartwood.

Emergence occurs in every month of the year but mainly in May, June and in September. The larval life is variable and in some individuals may be prolonged for two years while other individuals of the same brood may develop in less than a year. The larva is described and figured by Gardner, 1927, *Ind. For. Rec.*, XIII, ii, p. 39, figs. 7, 16, 32.

Economic importance: The species notable in

India and Ceylon as pest of avenue roadside trees and of shade trees in tea plantations particularly of *Albizzias*, attacking those that are injured or sickly and hastening their death. The less resistant trees may be killed in one season by a heavy infestation; more resistant trees may produce callus that restricts attacked patches of bark. *X. globosa* is also a pest in Malaya, and in Egypt was responsible for the disappearance of *Albizzia lebbek* in several cities.

For control see Part Two.

Zoodes basalis in *Quercus incana*.

Zoodes compressus, C, 7 mm., in *Acacia catechu*.

CHRYSOMELIDAE

OVER 20,000 species of beetles grouped in 16 subfamilies comprise the CHRYSOMELIDAE. Ten percent of these make up the Indian fauna which is completely monographed by Jacoby (1908) and Maulik (1919–1936). All members of the family are phytophagous and especially on foliage, hence the name 'Leaf Beetles' often bestowed on them. Although abundant and ubiquitous in forests they do not cause appreciable damage except in pure plantations or in stands of gregarious species. During a survey of the insect fauna of *Santalum album* in south India 243 species of Chrysomelidae were found to frequent the foliage of this tree; some species, e.g., *Hyphasoma tenuilimbatus*, occured on the foliage steadily throughout the year, yet neither this or any of the 243 species feeds on sandal.

Cassidinae amount to about 3,000 species of which 160 are found within the Indian region. All are defoliators, as beetle and larva, of trees, shrubs and climbers. Typical beetles of the Cassidinae are more or less convex above and flat below with the margins of the elytra flattened to a rim; hence they are popularly known as 'Tortoise Beetles'. The eggs are laid either singly or in clusters in an ootheca, a mass or layers formed of a dried fluid secretion. The larvae are leaf-eaters, feeding exposed, and retaining the excrement (and sometimes the larval moults) which is carried as a bunch of filaments or a solid mass at the end of the abdomen. In *Aspidomorpha* and *Calopepla* the larval excrement is carried in bunches or brushes of long filaments. [fig. 70]. In *Oocassida* and *Laccoptera* the excrement is in the form of a solid lump carried on a long terminal or paired fleshy process. Larval descriptions are given in Maulik's *Fauna* volume on the subfamily.

The Chrysomelinae are a subfamily of about 2,500 species with less than 100 in the Indian region; the larvae feed openly on the foliage of plants in the company of the adults.

The Clytrinae are represented by about 150 species in India s.l.

Cryptocephalinae have about 170 species in the region. The large genus *Cryptocephalus* contains thick-set cylindrical beetles

coloured yellow or orange and black. The larva has the white curved and swollen abdomen protected by a sack or case formed of larval excrement from which the head and legs protrude. [fig. 72].

Eumolpinae are an immense complex of genera represented by about 450 species in the region. The larvae are mainly root feeders; numerous species live free on plants or more rarely within them; they do not construct cocoons or cover themselves with excrement. The beetles have the head bent down and largely concealed by the front of pronotum.

Galerucinae: Over 400 species occur within the Indian limits and all live on green plants. The beetles vary in size from 3–17 mm. Eggs are laid in soil or on bark sometimes covered with faecal matter. The larvae bore green stems and roots or feed on leaves perforating or skeletonising them. Pupation occurs in the soil. Hibernation usually takes place as beetle.

Halticinae amount to over 300 species in the Indian region; the majority are 'flea-beetles' several species of which attack crops and some of which are leaf-miners in the larval stage; some of the larger forms, e.g., *Ophrida*, *Podontia*, are defoliators of trees, the larvae and beetles feeding gregariously.

Hispinae are all plant-feeders and several are pests of trees or bamboo. Some of the beetles of the Hispinae are remarkable for the development of the spines and tubercles in the elytra and thorax. Larvae of *Hispa*, *Platypria*, *Wallaceana* are illustrated in Maulik's *Fauna* volume on the subfamily.

From the forestry aspect the Chrysomelidae may be referred to the followihg biological groups:—

(a) Larva feeds openly on foliage...Most of the family.

(b) Larva mines in the leaf or green shoot, e.g., *Clitea*, *Sphaeroderma*, *Throscoryssa.*

(c) Larva bores in more or less woody stems, e.g., *Estigmena*, *Sagra.*

(d) Larva lives chiefly in the soil...Many Eumolpinae.

Life-histories of very few Indian species have been worked out. The life-cycle from egg to adult is irregular; the number of generations varies from one per annum, e.g., *Estigmena chinensis*, and 3, e.g., *Calopepla leayana*, to 5 in *Aulacophora foveicollis.*

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Garthwaite P.F., 1939, *Ind. For. Rec.*, Ent., V, No. 2, pp. 237-277, 2 pl. On the biology of Calopepla leayana (Chrysomelidae) and the possibilities of control.
Hingston R.W G., 1928, *Journ. Bomb. Nat. Hist. Soc.*, XXXIII, pp. 60-64, A shield making beetle, Sindia clathrata.

Aetheodactyla plagiata feeds on *Poinciania regia.*

Aetheomorpha nigropicta gnaws needles of *Pinus longifolia.*

Anisodera guerini bores green stems of *Costos speciosa.*

Apthona kanarensis on *Eucalyptus rostrata.*

Aphthona nigrilabris on *Pinus longifolia.*

Apophylia metallica defoliates *Cordia myxa.*

Aspidolopha thoracica defoliates *Xylia dolabriformis.*

Aspidomorpha miliaris feeds on *Ipomoea* spp.; the life-cycle takes one month to 6 weeks.

Maulik S., 1919, *Fauna Brit. Ind.*, Hispinae and Cassidinae, pp. 270-273, figs. 82-84 (biology, description and figures of larva and pupa), pp. 334-336, figs. 103, 104 (variation of beetle).
Corbett G.H. and Dover C., 1927, *Malay Agric. Journ.*, XV, pp. 256-262, The tortoise beetle, Aspidomorpha miliaris.

Aspidomorpha sanctaecrucis feeds principally on Convolvulaceae.

Maulik S., 1919, *Fauna Brit. Ind.*, Hispinae and Cassidinae, pp. 273-274, figs. 85, 87 (biology and descriptions of stages).

Aulacophora foveicollis a widespread galerucine species, feeds on many species of Cucurbitaceae and also as beetle on *Dalbergia latifolia, Michelia champaca* and *Tectona grandis.* The eggs are laid on moist soil at the base of the food-plant and hatch in 6–15 days; the larva is active, and bores into roots, stems, fruits and also feeds on leaves lying on the soil. There are 4 instars in a larval period of 13-23 days. Moulting and pupation take place in the soil; the pupa rests in a smooth-lined earthen cell for 7–17 days. The total life-cycle takes 32–55 days giving 5 generations from April to October and 5 or 6 months hibernation.

Afzal Hussain M. and Abdullah Shah S., 1926, *Mem. Dep. Agr. Ind.*, XI, pp. 31-57 (biology).
Maulik S., 1936, *Fauna Brit. Ind.*, Chrysomelidae, Galerucinae, pp. 28-31, fig. 19 (description of larva).

Calopepla leayana

L i f e - h i s t o r y: This cassidine beetle is oblong, one half to two thirds of an inch long, of brilliant metallic colouration, the elytra coarsely wrinkled and deep bluish-green in the young beetle, and deep violet-blue to black in the old beetle, the pronotum and legs are at first pale yellow and later deepen to reddish-brown. [fig. 4, No. 15 and fig. 70]. The elongate yellow eggs are laid vertically in clusters of 10 to 100, average about 60, and embed-

ded in a frothy secretion which hardens to form a domed brownish ootheca; each egg is thus in a cell about 3 times its diameter and twice its height. Oothecae are laid on the undersurface of leaves or on shoots.

The oviposition period may extend to six weeks and one female is able to lay about 23 egg-masses, i.e., over a thousand eggs. The oothecae of old females are smaller with fewer eggs. The length of life of the beetle is about 50 days (maximum 120 days) in the first generation, and six to eight months in the overwintering generation.

There are five larval instars, [fig. 70]. In all instars the larva is elongate and narrowed backwards and has pronotal spines on the thoracic and abdominal segments, the anterior pronotal spines being directed forwards and the 9th abdominal segment has a dorsal pair of short hooks. The colour changes from primrose-yellow in the 1st instar to pure black in the 5th instar. The moulted skins are accumulated and carried attached to the hooks on the last segment, and the excrement, instead of being rejected, is extruded in long, fine, black filaments often twice the length of the body which are formed into bunches also attached at the anal end. When disturbed the larvae of all instars flick these filaments up and down in a defensive or frightening action. The full grown larva pupates on a leaf fastening itself by the first three abdominal segments and casting off the filaments of excrement and the previously moulted skins. [fig. 70]. Pupation occurs by means of a split down the median line of the larval thorax and the pupa gradually works the larval skin backwards until it forms a crumpled mass at the anal extremity. During the course of pupation the last abdominal segment of the pupa is stuck to the leaf and thus the mottled yellow and black pupa is able to move only the anterior part of the body.

There are three generations a year at Dehra Dun and two generations with a partial third at Maymyo, Burma. Hibernating beetles of the previous year do not become active until the end of the leafless period in the dry hot weather, that is in April in Maymyo, and in May in Dehra Dun. In the first generation at Dehra Dun the life-cycle from egg to egg occupies about 39 days (egg 5 days, larval period 15 days, pupal period 5 days, pre-oviposition period 14 days). In Maymyo the average life-cycle is 50 days (egg 7 days, larval period 21 days, pupal period 7 days, pre-oviposition period 15 days). The second generation takes about 35 days at Dehra Dun and a minimum of 43 days at Maymyo. In the third generation the total life-cycle occupies 260–270 days, September to June, of which about 8 months is passed as a beetle. Hibernation and aestivation occur in cracks and holes under the dead bark of standing trees, in hollow bamboos, in grass clumps and thatch and in curled dry leaves on the ground.

E c o n o m i c i m p o r t a n c e: The beetle feeds on the leaf,

cutting large circular holes and also eats the young buds and shoots. The larva in its early stages eats the leaf parenchyma preferably on the underside. From the beginning of the 4th instar the larva eats more voraciously and chews holes in the leaves; complete skeletonisation leaving only the midrib and main veins intact is characteristic of the 5th instar larva.

Defoliation of *Gmelina arborea* is first noticeable at the beginning of the rains and may continue till October. The species is a serious pest of plantations of the tree in Assam, Bengal and Burma and occurs wherever the tree is grown. A heavy attack causes the leading shoots of young trees to dry up and the trees remain leafless for about four months of the growing season and eventually become bushy; with two or more consecutive complete defoliations the tree will be killed. Where the pest is serious the planting of pure *Gmelina arborea* has been abandoned. In the Northern Shan States over 2,000 acres of plantations with a capital value of Rs. 4,50,000 had to be written off in 1936.

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Cassida belli defoliates *Coriaria nepalensis* in August.

Chrysochus nilgiriensis feeds on *Tectona grandis*.

Chrysomela chlorina, a shining bright green beetle, is a defoliator of *Alnus nepalensis* in the E. and W. Himalayas.

Clitea picta. Life-history. This halticine beetle, oval, 5 mm., mottled brown and black [fig. 71] feeds on the leaves of *Aegle marmelos* forming numerous small holes; it leaps actively when disturbed. The eggs are laid on the leaf and the larva burrows into the midrib of the leaf, into the young shoots, spines and axils of branches and occasionally into the young setting fruits, the bored parts swell to some extent and a transparent resin exudes (Fletcher). The larva [fig. 71] is about 8 mm. long and 1·5 mm. broad, convex, and dull brown or orange yellow in colour; over the anus is a large dark plate. Pupation takes place either in the larval tunnel or in the soil in earthen cocoons. The period of defoliation is in June and July.

Clitena limbata feeds on *Tectona grandis*.

Clytrasoma conformis feeds on *Glochidion velutinum*.

Colasposoma asperatum and **C. villosulum**, bright green eumolpine species sometimes with red and blue metallic reflections, 5–6 mm., long, [fig. 4, No. 16], are defoliators of *Tectona grandis* in Burma and Madras; the former also feeds on *Cratoxylon* sp.

Colasposoma downesi also defoliates *Tectona grandis*.

Colasposoma metallicum, a blackish-bronze or bluish beetle, 6-7 mm. long, feeds on *Gmelina arborea* in Burma.

Colasposoma semicostatum, 4-5 mm., long, occurs throughout India frequenting the foliage of numerous trees; it gnaws the needles of *Pinus longifolia* and the leaves of *Citrus* sp., *Tectona grandis* and *Vitex negundo* in March to July.

Corynodes peregrinus occurs throughout India; it feeds on *Tectona grandis* and other trees.

Corynodes pyrophorus on *Cordia myxa* and *Jasminum arborescens*.

Crioceris impressa feeds on flowers of *Callicarpa macrophylla* and on *Dioscorea alata*, *D. bulbifera* and *D. tomentosa* and on the leaves of *Ficus elastica*, and *Holarrhena antidysenterica*.

Crioceris quadripustulata on *Trewia nudiflora*.

Cryptocephalus dodecaspilus, 4 mm., occurs on *Quercus dilatata*, *Pieris*, *Salix*, *Pyrus*, etc.

Fig. 69. Damage to wood by Cerambycidae

No. 1. *Stromatium barbatum*—A plank of *Alnus nepalensis* seen from two aspects and showing larval tunnels and beetle of *S. barbatum*; the outer faces of the plank have been removed and the wood-dust has been cleaned out of the larval tunnels leaving the intervening lamina of uneaten wood.

No. 2. *Dihammus griseoplagiatus*—longitudinal section of a log of *Lannea grandis* showing pupal chamber, exit-hole and beetle of *D. griscoplagiatus*; the prepupal tunnel is packed with wood-fibres and the exit-hole is on the sapwood surface (left) opposite the base of the pupal chamber.

No. 3. *Criocephalus tibetanus*—longitudinal section of a stump of *Pinus excelsa* showing larval tunnel, pupal chamber and beetle of *C. tibetanus.*

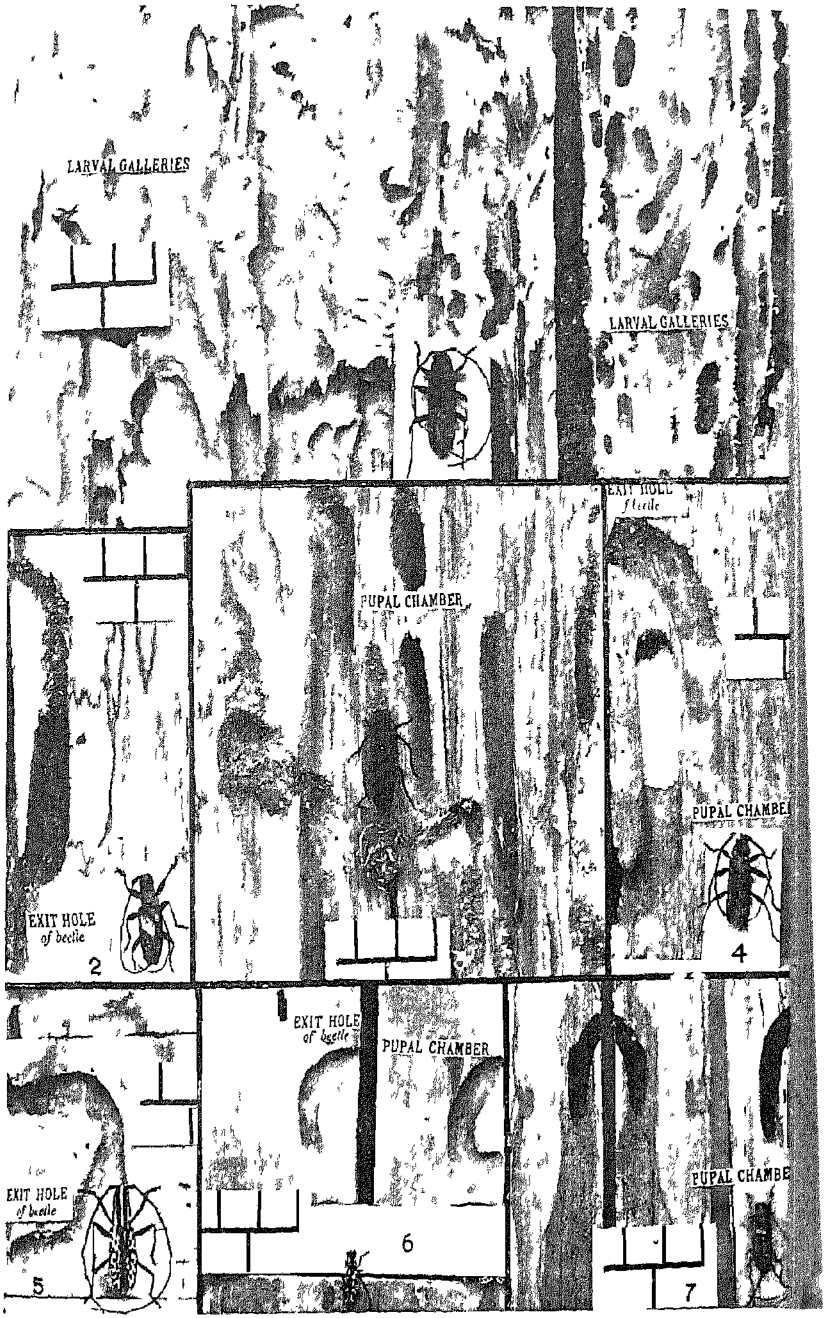
No. 4. *Xystrocera globosa*—Longitudinal section of a log of *Albizzia stipulata* showing pupal chamber, exit-hole and beetle of *X. globosa*; the pupal chamber is lined with a film of calcium carbonate, one is directed upwards the other downwards; the exit-hole is on the surface of the sapwood (left).

No. 5. *Macrochenus tigrinus*—Longitudinal section of *Artocarpus integrifolia* showing pupal chamber and beetle of *M. tigrinus;* the exit-hole is on the sapwood (left) opposite the base of the pupal chamber.

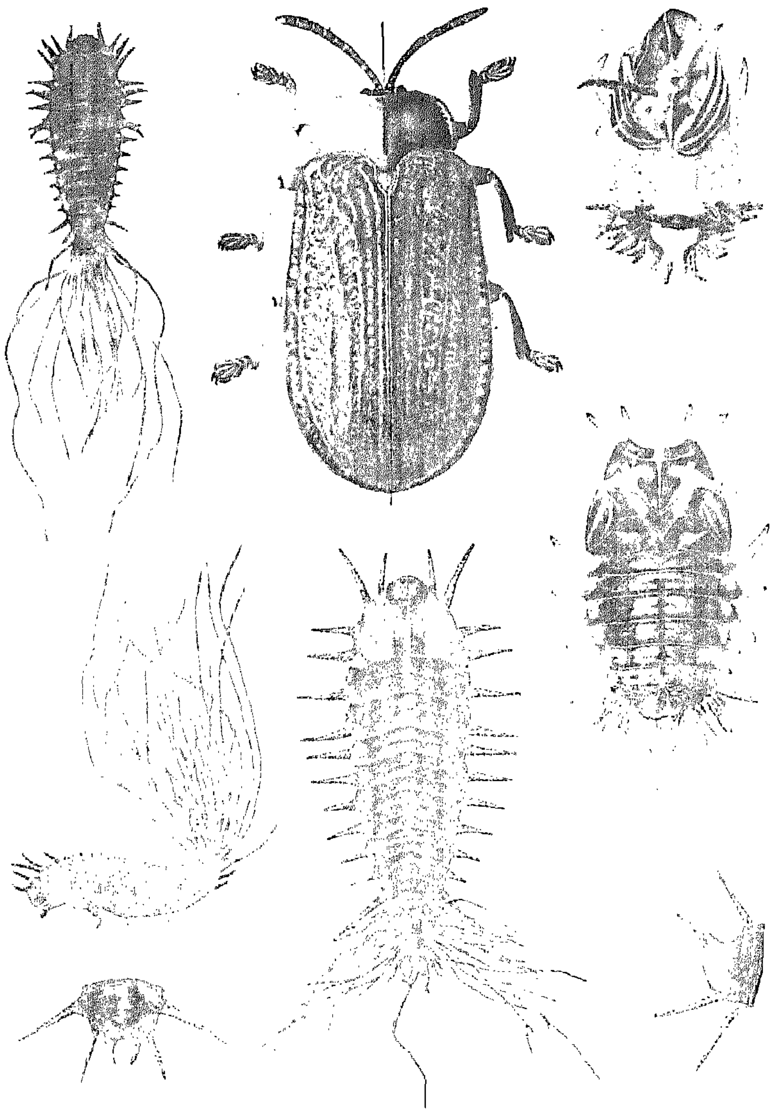
No. 6. *Cylindreponius signatus*—Wood of *Adina cordifolia* showing pupal chamber and beetle of *C. signatus.*

No. 7. *Olenecamptus bilobus*—Longitudinal section of *Ficus religiosa* showing pupal chamber and beetle of *O. bilobus.*

All photographs to the same scale; reduction is indicated by the inch-centimetre scales.



LARVAL GALLERIES
LARVAL GALLERIES
EXIT HOLE
PUPAL CHAMBER
EXIT HOLE
of beetle
2
PUPAL CHAMBE
4
EXIT HOLE
of beetle
PUPAL CHAMBER
EXIT HOLE
of beetle
5
6
PUPAL CHAMBE
7



Cryptocephalus konbirensis, 3–4 mm., feeds on *Celtis tetrandra.*

Cryptocephalus pusaensis, 3 mm., feeds as larva and as beetle on the shoots of *Tamarix gallica.*

Cryptocephalus sehestedti, 2–3 mm., damages seedlings of *Casuarina equisetifolia.*

Cryptocephalus sexsignatus, 5–8 mm., feeds on dry fallen leaves throughout India. The larva is enclosed in a bag about 7–13 mm., long and 4–8 mm., wide, which it carries about and in which it can shelter; the bag is eventually closed and used for pupation. [see fig. 72 a, b, c; also fig. 4, No. 17, variety of beetle].

Diapromorpha balteata defoliates *Acacia arabica* and *Cassia siamea.*

Dercetis posticata defoliates *Stephegyne diversifolia.*

Diorhabda trirakha defoliates *Ulmus wallichiana.*

Diorhabda lusca. The beetles and larvae defoliate *Celtis australis, C. occidentalis* and *C. tetrandra,* particularly in May, June.

Episticta viridimaculata defoliates *Stereospermum suaveolens.*

Estigmena chinensis.

The known food-plants of this hispine species are *Bambusa arundinacea, B. burmanica, Cephalostachyum pergracile, Dendrocalamus strictus.* It is a serious pest of bamboo forests in India and Burma. The beetle, 10–16 mm., is elongate, parallel sided, varying in colour from light brown to black and usually dark.

Life-history: Overwintered beetles [fig. 4, No. 13] become active before the onset of the monsoon but oviposit during the first four to six weeks. The maximum number of eggs laid by a female is 12, deposited in batches of 2 to 4 on the surface of the internode under the free part of the culm sheath and covered with chewed up fragments of leaf so that they may be mistaken for pellets of excrement. The larvae feed for a while between the the culm sheath and the surface of the culm eating out irregular

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Fig. 70. Calopepla leayana, defoliator of Gmelina arborea

Top left—4th instar larva; top centre—beetle; top right—pupal skin after emergence of beetle, with last larval skin attached.

Bottom left—4th instar larva, lateral view, showing caudal filaments carried erect; below is the 9th segment of the 5th instar larva showing the spiked appendages after the larval skins and filaments have been shed; bottom centre—5th instar larva.

Centre right is the pupa and below it is the 9th segment of the 5th instar larva showing the spiked appendages after the larval skins and filaments have been shed.

The magnification of all figures (except the 9th segment) is about six times natural size.

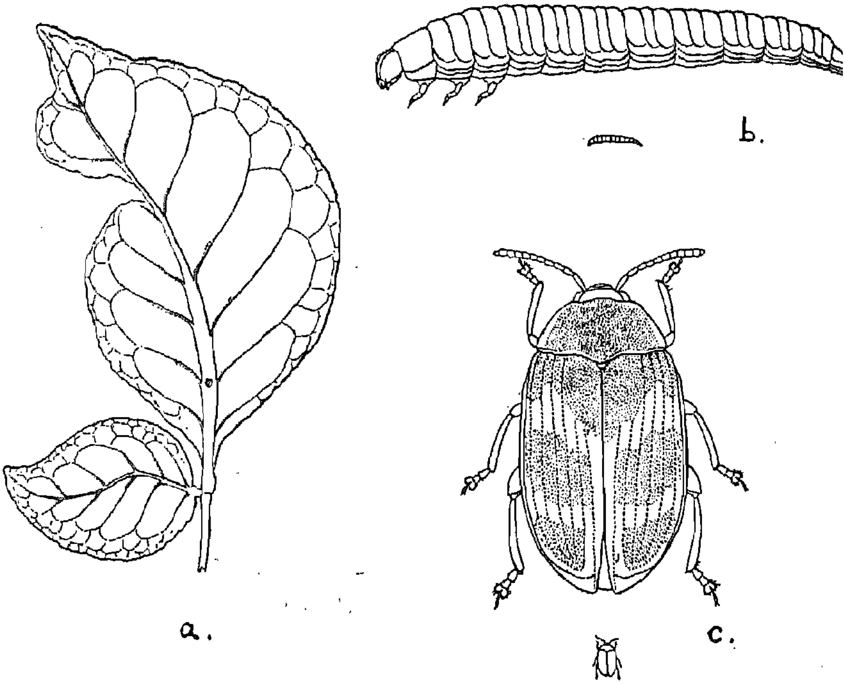

Fig. 71. Beetle and larva of Clitea picta (Chrysomelidae); the small figures are natural size; the leaf of *Aegle marmelos* is bored inside the midrib.

broad or lobed shallow patches in the tender outer tissues. During their early work several (about a dozen) young larvae may feed together in one patch but later they separate. About the time that the culm sheaths begin to dry up or fall off towards the end of the rainy period the larva bores into the wall of the internode and excavates a tunnel up and down its length. Fine wood-dust is ejected from the hole in the internode wall. Each internode may have one to five larval galleries in it running longitudinally for a few inches and sometimes traversing the internode. At the end of August in north India practically all the larvae are in the last stages. Pupation begins in September and after a short pupal period the beetle is formed. From October onwards through the cold weather and hot dry weather the beetle remains in the larval tunnel inside the wall of the internode. The tunnel is enlarged from time to time into an irregular chamber, apparently for purposes of feeding, and finely abraded moist dust is ejected from the hole. The hole is elongate with sharp edges due to deformation during the growth of the internodes; tunnels are sometimes carried into side shoots that are thicker than a pencil.

E c o n o m i c i m p o r t a n c e: The damage by this insect appears to be most frequent in solid bamboos of small dimensions and in the solid part or the thick walls of large hollow bamboos. Thin walled hollow bamboos are not usually attacked. The damage is done to the bamboos in the first few months of growth. Second year and older culms are very rarely inhabited by beetles. *E. chinensis* is most abundant in young clumps where culms of the preferred type are available. It appears to be rare in very dry bamboo forests and in dense shady bamboo areas unworked for more than four years.

The effect of the boring of *E. chinensis* is (*a*) decrease in adjoining internodes, when the attacked part is very young, and lateral shrinking on the side damaged, and (*b*) reduction in the sale value of the bamboo, especially solid bamboo.

If the bamboo is cut or dries up, the beetles leave the dry material but they do not vacate the chambers in living bamboo until rain falls. Early showers, which cause the emergence of beetles before the monsoon growth of the bamboo commences, are responsible for a high mortality of beetles without oviposition.

Eubrachis indica. The beetle defoliates *Aesculus indica*; the larva lives in soil near rootlets.

Galerucida rutilans on *Desmodium sambuense* and *Pinus longifolia.*

Haltica cyanea is a general feeder particularly common on *Ammania baccifera, A. rotundifolia,* stinging nettles and other weeds and has been found defoliating *Terminalia myriocarpa* seedlings and plantations.

Hispa armigera, a defoliator of paddy, sometimes attacks *Tectona grandis.*

Hoplosoma sexmaculata on *Celtis tetrandra, Pinus longifolia* and *Quercus incana.*

Hoplosoma unicolor on *Clerodendron infortunatum, Michelia champaca.*

Hyperascis malabarica bites off the leading shoots of young seedlings of *Hopea parviflora* in September–November.

Lygaria westermanni defoliates *Heterophragma adenophyllum.*

Melasoma populi. This chrysomeline beetle has the elytra bright yellow or red and the thorax blue, length about 2/5ths of an inch. The beetles overwinter in the soil or humus, etc., and emerge in spring with the appearance of new foliage. Eggs are laid in clusters of 20–30 on the underside of leaves. The larvae feed by skeletonising the leaf until only the veins are left. The full grown larva is plump-bodied, whitish with rows of black spots and a black head. After about three weeks, pupation takes place on the leaf; the pupa hangs suspended from the leaf by the tip of the abdomen. The pupal period lasts about 10 days. Two or three broods may occur in the season.

E c o n o m i c i m p o r t a n c e: This widely distributed species

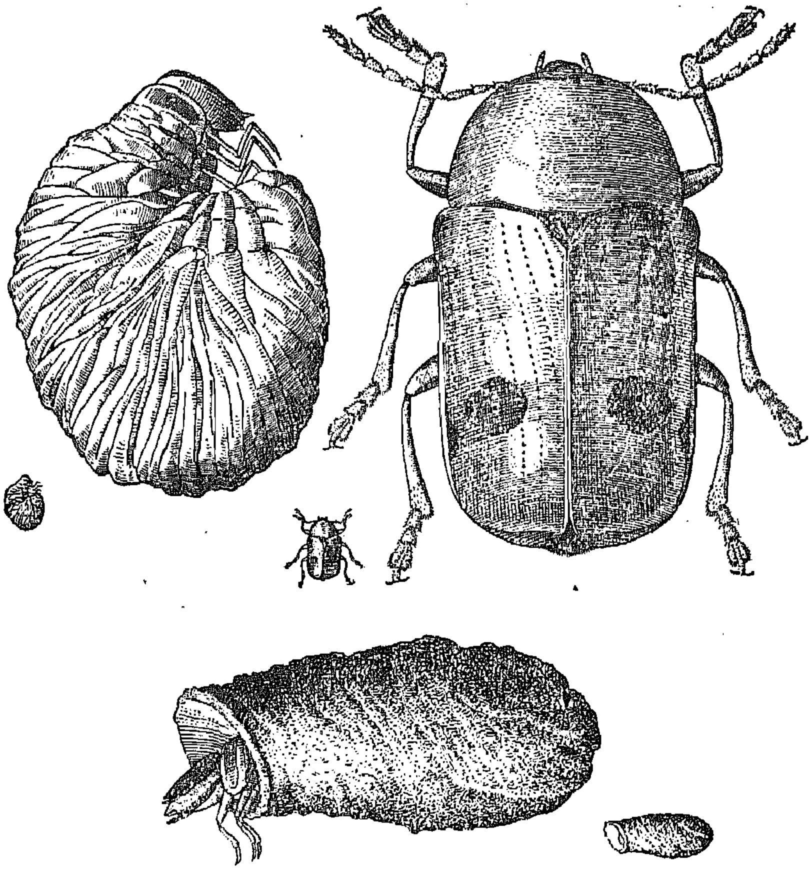

Fig. 72. Cryptocephalus sexsignatus. Beetle and larva; the small figures are natural size; the larva is shown in its shelter-case (below) and removed from the case, with its abdomen contracted (above left).

is a pest of willows and poplars in the north temperate region. At high elevations in the Himalayas it feeds on *Salix babylonica*, *S. denticulata*, *S. elegans* and *S. tetrasperma*, and *Populus ciliata*.

Mimastra cyanura, a widespread galerucine species, as beetle feeds on *Celtis australis*, *C. tetrandra*, *Dalbergia sissoo*, *Grewia asiatica*, *Mallotus philippinensis*, *Morus alba*, *M. serrata*, *Pyrus communis*, *Prunus armeniaca*, *P. malus*, *P. pashia*, *Trema bracteolata*, and other trees. The larvae live in the soil. The beetle emits an acrid yellow fluid from the head.

Mimastra gracilicornis feeds on *Tectona grandis.*

Monolepta khasiensis defoliates *Zizyphus jujuba.*

Nodostoma bhamoense, a eumolpine, 4 mm., defoliates *Tectona grandis* in Burma and south India.

Nodostoma dimidiatipes, 3 mm., defoliates *Tectona grandis* in south India.

Nodostoma waterhousei, 4 mm., feeds on *Populus ciliata.*

Oocassida cruentata and **O. pudibunda** feed on *Zizyphus jujuba.*

Ophrida hirsuta. This halticine beetle is about ½ inch long, yellow with brown speckling and feeds on *Boswellia serrata.*

Periclitena vigorsi defoliates *Cordia myxa* and *Rhamnus purpureus.* The larva is described by Maulik, 1936, *Faun. Brit. Ind.*, Galerucinae, pp. 34–37, fig. 21; beetle pl. I, fig. 1.

Phyllotreta downesi on *Crataeva lophosperma.*

Plagiodera rufescens. The beetle, 5 mm., and larva feed on *Carissa spinarum, Flacourtia ramontchi* and *Gymnosporia championis.*

Plagiodera versicolora, a chrysomeline, 4 mm., as beetle and larva, defoliates *Salix alba* in Kashmir and *Salix tetrasperma* in India in April–June.

Platypria andrewesi. The larva feeds on the leaf of *Zizyphus jujuba* eating out several mines or pockets in one of which it pupates. The larva is flat and yellowish-white and smooth with the body segments produced at the sides in a short backwardly curved hook. The beetle, a hispine, is yellow or reddish-brown armed with numerous flat black-tipped spines, length 5 mm.

Platypria echidna, P. erinaceus and **P. hystrix** defoliate *Desmodium gangeticum, Erythrina, Pueraria tuberosa* and *Zizyphus* spp.

Podontia 14-punctata. This halticine beetle is oblong, ½ to 2/3rds of an inch, pink, the elytra with 6 black spots each and 2 black spots on the suture. [fig. 4, No. 14]. The eggs are laid on the leaves. The larva is plump and wrinkled, yellowish-brown with a black head and a black patch on the thorax and small spots on the abdomen, but it covers its body with its excrement so that it resembles closely the dropping of a bird. The leaves are completely stripped down to the midribs. For pupation the larva drops to the ground and forms its cocoon of particles of earth in the soil.

The principal food-plant is *Spondias mangifera; Duabanga sonneratioides, Ficus elastica* and fruit trees are also attacked. The chief period of defoliation is in August and September.

Prioptera maculipennis, a cassidine species, 9 mm., defoliates *Gmelina arborea.*

Prioptera punctipennis, a convex beetle with a flat rim to the elytra, brown with 2 black spots, 10 mm., occurs sometimes with *Calopepla leayana* as a defoliator of *Gmelina arborea* in Burma, and Bengal. The insect passes the cold season as a beetle

sheltering in dead leaves and crevices. After about five months (November to April) the eggs of the first generation are laid in April in a covered mass on foliage; hatching takes place in six days. The larval period is 16 to 19 days in May and the pupal period about 5 days. Eggs of the second generation are laid at the end of May and beginning of June. The last generation pupates in November with a pupal period of 12 to 14 days.

In the genus **Sagra** (Sagrinae) the larva feeds inside the stems of creepers or lianes causing large gall-like swellings. When these climbers encircle the stems of trees in vigorous growth so that the climber is partially occluded in the bark or sapwood of the tree, the larva of *Sagra* may continue its tunnel into the wood of the tree and usually does so eventually for pupation. The pupal chamber is about an inch long, clyindrical with round ends and lined with a thin black water-proof layer.

Sagra femorata, a blue species, 16–20 mm., feeds as larva boring in stems of *Dolichos lablab*, *Fabia vulgaris* and *Mucuna atropurpurea*.

Sagra jansoni, a smaller beetle, 12–14 mm., with green, red and blue metallic reflections, pupates in teak saplings in Burma.

Sagra longicollis, a bright metallic blue beetle about 20–22 mm. long with very long hind legs, [fig. 4, No. 12], forms galls in various climbers including *Thunbergia grandiflora*. The larva is white, fleshy, and transversely wrinkled. Its pupal chambers have been found in teak saplings in groups of 4 or 5.

Sebaethe brevicollis feeds on *Tectona grandis*.

Sphaeroderma brevicornis, 3 mm., a halticine, feeds and mines as larva in the leaves of *Bidens pilosa*.

Throscoryssa citri is a halticine leaf-miner of *Citrus* spp. in the Assam hills. Eggs are laid mainly on the lower surface of the leaf; several may be laid on one leaf. The larva eats out the tissue between the two leaf surfaces, frequently leaving the mine during the night by an exit-hole in the upper surface and re-entering the same or another leaf through the under surface. The larval excrement occurs as a continuous black line down the middle of the mine. The affected leaf turns yellow and when the attack is heavy all the foliage may be dropped. For pupation the larva drops to the ground and forms an oval cell in the soil. The larval period is 17 to 19 days, the pupal period is 10 to 12 days and the life-cycle from egg to adult is 35 to 40 days. There is only one generation in the year. The beetle, 3 mm., brown with black prothorax, rests in sheltered places from about June to March of the following year.

Wallaceana dactyliferae, a hispine, 6 mm., attacks the young leaves of the date palm causing the withering and death of the shoots.

CICINDELIDAE.

CICINDELIDAE or Tiger Beetles are not a large family; not more than 300 species occur in India, Burma and Ceylon, where they have been particularly collected. The conspicuously coloured, active, alert beetles are typical predators, hunting and feeding on other insects, especially ants, small beetles and bugs and also caterpillars and nymphs; or the dead bodies of large and more active insects are also eaten. They frequent open sunny places where the soil is sandy or dusty and also moist ground near streams and ponds *(Cicindela)*; others are predominantly arboreal, frequenting foliage and bark *(Collyris, Neocollyris, Tricondyla)*. The larval habits can be referred to two types, one living in burrows in the soil, and the other in shelter-tunnels in stems or twigs. Larvae are also predators but not active hunters; they remain in their tunnels lurking at the opening until the prey passes near enough to be seized.

In the soil-burrowing group *(Cicindela)* the egg is laid singly in a pit scooped out in the soil by the female and the larva deepens the pit to form a vertical or oblique burrow often many inches long. To fit it for a successful life as a predaceous burrow-dweller the cicindelid larva has evolved certain adaptations of its body. The head is strengthened and shaped for scraping and ejecting the excavated soil and for tamping and compacting the walls of the tunnel; the prominent and powerful jaws are directed upwards so that passing prey is readily caught. The body-muscles flex the swollen body into a curve so that it grips the sides of the tunnel firmly, and hooks or spines, developed on a protuberance of the 5th abdominal segment, anchor the larva and prevent it being pulled out of its shelter by a stronger captured prey; by releasing the grip of the spine and straightening the body the larva can drop instantly to the bottom of its burrow. The food of the larva consists of ants, beetles, flies and larvae of all sorts, spiders, centipedes, etc. Pupation takes place in a chamber at the side of the burrow.

In the twig-boring group *(Neocollyris, Tricondyla)* the female cuts a short vertical tunnel in the living twig with the hooks of the ovipositor and inserts one egg; the larva extends the tunnel as it grows but only sufficiently to make a secure retreat from danger or for undergoing moults and pupation.

Little is known about the length of the life-cycle in Indian Cicindelidae. *Necollyris bonelli* is reported to have one generation a year in Java and species of *Cicindela* in temperate regions may take 3 or 4 years to complete development. It is probable that the life-cycle is largely dependent on the quantity of the food obtained which is precarious at all times. Because of their restricted habitats and small populations the Cicindelidae do not play a major part among the predators controlling forest insect pests.

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Annandale N. and Dover, C., 1921, *Rec. Ind. Mus.*, XXII, p. 335-337. Cicindelid beetles of Barkuda Island.
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Fowler, W. W., 1912, *Fauna of British India*, Coleoptera, General Introduction. Cicindelidae, pp. 219-443, figs.
Gardner, J. C. M., 1930, *Ind. For. Rec.*, XIV, xiii, pp. 279, 280 (larva).
Gravely F. H., 1912, *Rec. Ind. Mus.*, VII, pp. 207-209. The habits of some tiger beetles from Orissa.
Heynes-Wood M., and Dover C., 1928, *Catalogue of Indian Insects*, Part 13, Cicindelidae, pp. 138.

Cicindela haemorrhoidalis. The larvae occur in termite-mounds unlike the majority of the species of *Cicindela* which burrow in soil.

Neocollyris bonelli, a slender metallic blue tiger beetle with a narrower thorax than that of species of *Cicindela,* length 12 mm., widely distributed in the Oriental Region with several varieties, lives as larva in a short tunnel in the pith of living twigs of the coffee tree, and of *Duranta, Swietenia macrophylla* and *Zizyphus jujuba.* The larva lies in wait with the head at the orifice of the tunnel and the mandibles widely opened to seize any small insect that may pass within reach; it throws its head suddenly forwards and thrusts its body for a short distance out of the hole, snapping at the prey, which if caught is at once dragged into the tunnel. Just before the prepupal stage the larva closes the entrance of the tunnel with a secretion from its mouth making a convex lid, thick at the edge but gradually thinner towards the centre where a minute aeration hole is left. The attacked stem swells somewhat and a larger cavity is formed in which pupation occurs. The life-cycle takes one year.

Neocollyris crassicornis, a beetle of similar appearance, lives as larva in a tunnel about an inch long and 1/8th of an inch in diameter in living twigs of the tea bush. The circular orifice of the tunnel has a bevelled or countersunk margin. The larva, about 17 mm., pinkish, has the body flexed and two humps bearing hooks on the dorsum of the fifth abdominal segment and small protuberances on the sides and ventral surface of the abdomen; the head is strongly sclerotised, shovel-shaped, and set at rightangles to the thorax.

The larva is described and figured by Gardner, 1930, *Ind. For. Rec.*, XIV, xiii, pp. 279, 280, figs. 1-7. It feeds on ants and aphids that pass near the hole. Pupation takes place in the burrow. The beetles emerge in April-May and the generation is annual. The female by means of the ovipositor cuts a hole in the twig to deposit the egg from which the larva subsequently constructs its own tunnel.

Andrewes E. A., 1929, *Quart Jl. Ind. Tea Assoc.*, pp. 45-50.

Neocollyris redtenbacheri has habits similar to those of the preceding species. The larval shelter is made in stems of *Clerodendron infortunatum*; it is 14 mm. long and 2 mm. in diameter and trends upwards from the hole.

Tricondyla cyanea, in Burma, is also a twig-boring species.

CISIDAE.

SMALL beetles resembling and often mistaken for Scolytidae, the CISIDAE have otherwise no interest for forestry. The beetles and larvae feed gregariously in burrows in fungi, sporophores of *Polyporus*, *Ganoderma*, etc., and in old wood rotted with fungus. Very few of the Indian species have been collected or named.

Pic M., 1937, *Ind. For. Rec.*, Ent, III, No. 5, pp. 123-126, Cis Latr. et anobiides nouveaux des Indes.

CISTELIDAE see ALLECULIDAE.

CLERIDAE.

THE beetles of the CLERIDAE are usually elongate graceful forms in size small up to about ½ an inch with striking, often beautiful, color-patterns; in North America they are called Checkered Beetles. The recent Indian collections have been studied by Corporaal (1926, 1939). The larvae are more or less hairy and elongate, cylindrical or flattened with a strongly sclerotised pronotum and a hard plate bearing horns or hooks (urogomphi) on the 9th abdominal segment; some, e.g., *Ommadius* [fig. 73, No. 26] are without urogomphi and the pronotum is not strongly sclerotised; colour whitish, pink, red, brown or violaceous. Several Indian species have been described by Gardner (1937).

E c o l o g y: The Cleridae are among the principal predators of small wood and bark-boring Coleoptera; they are predaceous in both larval and beetle stages, the larvae feeding on the eggs, larvae and pupae of the borers in their galleries and the beetles feeding on the adults of the borers. Some types feed on other coleopterous predators and hymenopterous parasites in the same environment. Another feeds on the larvae and pupae of small bees nesting in hollow twigs. *Necrobia* feeds on dried coconut and carrion.

Clerid beetles are active hunters by day, most species working over infested timbers or haunting flowers and leaves in the sunshine; a few are nocturnal. They catch bark and wood-frequenting insects, Bostrychidae, Anobiidae, Scolytidae, Platypodidae and other small Coleoptera. The clerid sits upright balanced by the tip of the abdomen against the bark grasping its prey in the forelegs while the soft parts of the body are eaten, and the hard exoskeleton is rejected.

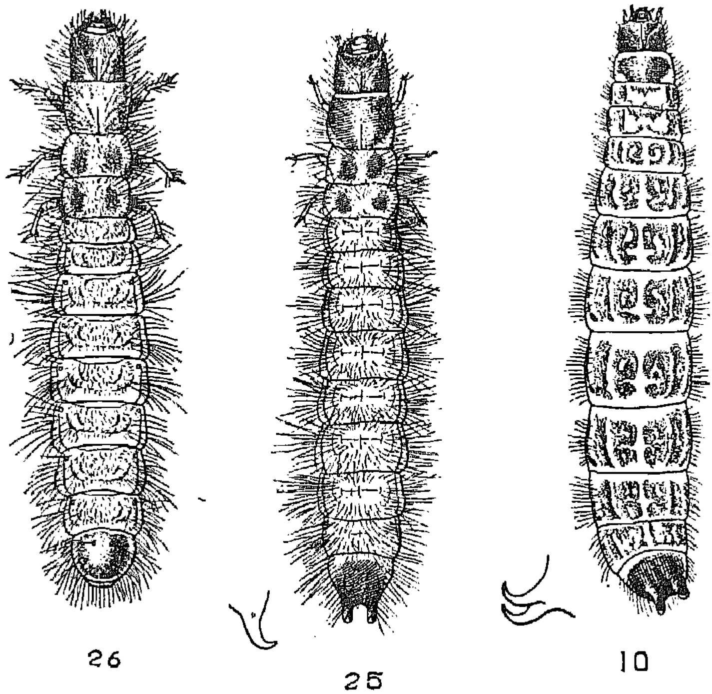

Fig. 73. Larvae of Cleridae

No. 26. *Ommadius* sp., natural size 16 mm.

No. 25. *Dasyceroclerus torulentus,* natural size 12 mm., predaceous on larvae of bark-boring Scolytidae.

No. 10. *Tillus succinctus,* natural size 20 mm., predaceous on bamboo Bostrychidae.

The eggs are laid in or near the entrance-tunnel of the host and the larvae explore the tunnels of the boring larvae, feeding on all stages that are discovered; they pass from one tunnel to another through the intervening bark. In the intervals between the discovery of borers the clerid larva may subsist on the excrement or boring-refuse in the tunnels or on other predators. The mature larva may survive a considerable time without taking food. Pupation takes place in a pupal cell made in the bark or wood or in the tunnel of the host. Some species line the cell with a white silvery exudation; others seal up the ends of borer-cells; others cement particles of wood or bark-dust or earth together to make the cell-wall. The exit-hole in the bark is sometimes previously sealed with a tough papery disc.

The majority of species have a life-cycle longer than those of their principal hosts, but usually development is completed in annual cycles or twice yearly, i.e., from eggs laid in April emergence may occur in October or in the following April. A few species with short life cycles are closely synchronised with their hosts.

Economic importance: Under natural conditions their economic importance as checks on the numbers of injurious borers is not striking. But under artificial conditions, e.g., in felling-refuse, in fuel and bamboo-depots, timber-yards, and in wood-using industries generally, where the borers occur in greater concentration, the efficiency of Cleridae is much higher and more evident. On an average the adult population of clerid and histerid predators amounts to about one fiftieth of the population of beetles of *Dinoderus* spp. in a bamboo-depot, as against a population of hymenopterous parasites amounting to one fifth of the adult borer-population. Where conditions remain sufficiently stable for periods long enough to permit the full development of natural control the parasite-population exceeds the borer-population and the predators' incidence rises considerably. Adults of *Tillus notatus* have been observed in abundance equivalent to 20 percent of the adult population of *Dinoderus ocellaris*. The number of *Dinoderus* beetles and larvae that one *Tillus* can destroy in the course of its life-cycle must amount to scores but the maximum potential rate of destruction must depend on an excessive and readily accessible population of *Dinoderus*.

The genera *Dasycerocierus*, *Thanasimus*, etc., which are predaceous on scolytid bark-borers, often appear as formidable enemies, the beetles hunting the scolytid beetles, and the larvae tunnelling in bark in search of the scolytid larvae. Stebbing observed that *T. himalayensis* ate small scolytid beetles at the rate of about one an hour. For a North American *Thanasimus* it is estimated that 20 to 25 beetles of *Dendroctonus* (Scolytidae) are consumed by one clerid beetle during its whole adult life and at least an equal number of *Dendroctonus* larvae during its larval life. Species of *Thanasimus* have been introduced into North America, Java and Ceylon because of this reputation but without success. A species of *Callimerus* predaceous on caterpillars was tried in Fiji but it did not establish. In their own particular life-communities they are effective but are too specific in their tropisms to succeed when introduced in a new environment. The Cleridae have specialised on prey of somewhat uniform habitats and developmental patterns and there is evidence of a tendency towards the circumscribed obligatory host-relation that is characteristic of parasitism. Parallelism in the development of predator and prey is indicated by the general fact that the beetles of Cleridae prey principally on the beetles and the larvae feed chiefly on the immature stages of the same species (Balduf).

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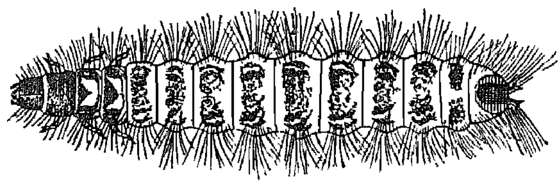
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Fig. 74. Larva of Opilo discodirus, natural size 20 mm., predaceous on larvae of Cerambycidae.

Anthicoclerus ruficollis is predaceous on barkbeetles, e.g., *Hypocryphalus mangiferae*, *Sphaerotrypes siwalikensis* and possibly small longicorn larvae. It emerges in April–June.

Beetles of **Callimerus** frequent foliage of trees and the larvae of some species are predaceous on leaf-eating caterpillars. One species *C. arcufer* was introduced from Malay where it feeds on the caterpillars of *Artona catoxantha* (Zygaenidae) to Fiji in order to control *Levuana iridescens*, the Coconut Moth.

Cylidroctenus chalybeus is predaceous on *Lyctus africanus* and *Minthea rugicollis*, *Trogoxylon spinifrons* (Bostrychidae); emergence occurs mainly in June–July. The larva, 15 mm. long, is described by Gardner, 1937, *Ind. For. Rec.*, Ent. III, No. 2, p. 36, fig. 14.

Cylidrus beesoni has black elytra with a common ivory-white patch, abdomen and legs yellowish, length 5–8 mm. It is predaceous on *Xylodectes ornatus* (Bostrychidae). There are two generations in the year producing beetles in March–May and October, November.

Cylidrus cyaneus, a metallic blue beetle, widely distributed in the Oriental and Australasian Regions, occurs in association with various Bostrychidae including *Sinoxylon anale*, *S. crassum*, *S. conigerum*, *S. tignarium*, *Xylodectes ornatus*, *Xylopsocus capucinus*, *Xylothrips flavipes* and various bark-borers of other families. The beetles emerge at any time between April and September. The larva, 18 mm. long, is desciibed in 1937, *tit. cit.*, p. 36, figs. 15, 16.

Cylidrus wallacei is predaceous on *Xylothrips flavipes* (Bostrychidae).

Dasyceroclerus torulentus is predaceous on small Scolytidae

(*Hypocryphalus mangiferae*, *Hylesinus javanus*, *Polygraphus*, *Sphaerotrypes siwalikensis*, *etc.*,) in many species of trees. The adults from the spring generation may mature in September, October or may carry on through the cold weather and emerge in April, May. The larva, 12 mm. long, described in 1937, *tit. cit.*, p. 42, figs. 23–25. [fig. 73, No. 25].

Elasmocylidrus tricolor, black with basal half of elytra red and a transverse band in middle yellow, 8 mm., is an associate of species of *Sinoxylon* and *Xylodectes ornatus* (Bostrychidae) and has one to two generations a year maturing in April, May, and in November, December.

Necrobia rufipes. The Copra Beetle. The larva feeds on dried coconut and copra, on carrion, hides, etc. and is a pest in the copra industry. There are several papers on the biology and economic importance of this species.

Corbett G. H and Dover C., 1927, *Malayan Agr. Jl.*, xv, pp. 239-271, pl. 5. The life history and control of some Malayan insects of economic importance.

Gardner J C. M., 1937, *Ind. For. Rec.*, Ent., III, No. 2. pp. 32, 43, fig. 34.

Nodepus conicicollis is probably predaceous on *Lyctus africanus* and young larvae of *Sinoxylon anale* (Bostrychidae).

Species of **Ommadius, O. mediofasciatus, O. roepstorffi,** and **O. tricinctus** are predators of borers in *Amoora wallichii*, *Dipterocarpus pilosus*, *Mimusops littoralis*, *Ostodes paniculata*, *Protium serratum*, *Terminalia procera*, *Sterculia colorata*. A larva of *Ommadius* is shown in fig. 73, No. 26. The prey consists of Scolytidae and small Curculionidae. The beetles emerge in April, May.

Opilo discodirus, thorax blackish with reddish patch, elytra brownish-yellow, 11 mm. long, is predaceous on the small larvae of Buprestidae and Cerambycidae (e.g., *Acmaeodera*, *Agrilus*, *Anthaxia*, *Cacia*, *Ceresium leucosticticum*, *Demonax formicoides*, *Exocentrus*, *Pterolophia occidentalis*, *Ropica honesta* and *Olenecamptus* spp.) Beetles emerge in June, July. The larva, [fig. 74], 20 mm. long, is described by Gardner, 1937, *Ind. For. Rec.*, Ent., III, No. 2, p. 41, figs. 17–22. The pupal chamber is closed with a tough papery disc but the walls of the chamber are not lined.

Pelonium extraneum is probably predaceous on small larvae of Buprestidae and of *Coptops*, *Diorthus*, *Demonax*, *Perissus*, etc. (Cerambycidae).

Pelonium gardneri is predaceous on small Cerambycidae and Buprestidae. The larva is described in 1937, *tit. cit.*, p. 37, figs. 29–33.

Psuedoclerops dealbatus, a species from Siberia and Korea, occurs in *Pinus khasya* in Assam as a predator of bark-borers, *Blastophagus*, *Polygraphus* (Scolytidae).

Tarsostenus univittatus. The beetle is somewhat flattened and narrow, metallic black with a whitish transverse band on

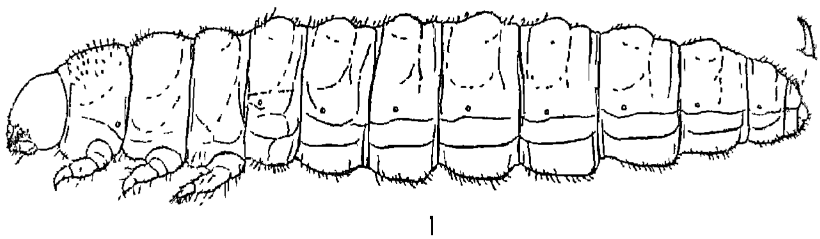

Fig. 75. Larva of Tenerus quadrimaculatus, natural size 12 mm., predaceous on small Cerambycidae.

elytra, 7–12 mm. long. The larva, 7 mm. long, is described in 1937, *tit. cit.*, p. 44. The principal host of *T. univittatus* in northern India is *Lyctus africanus*; it is also associated with *Trogoxylon spinifrons* and in south India with *Lyctus brunneus* and *Minthea rugicollis*.

The life-history of *T. univittatus* is subject to considerable variation. In north India the emergence-period may extend from April to December with no appearances in January–March; as a rule there are two occasions at which swarming takes place in greater numbers—the first in May and the second in August or September. The life-cycle is normally annual, but development may be delayed for 15 to 24 months; emergence of individuals in their second season (from both spring and autumn eggs) usually occurs about May. The chief host, *Lyctus africanus*, normally has two well marked flight-periods culminating in May and in August–September and also carries over to the second and later seasons.

Species of the genus **Tenerus**, include yellow beetles with black markings variable in extent, e.g., **T. femoralis**, **T. javanus**, **T. praeustus**, **T. proximus**, **T. quadrimaculatus** and **T. signaticollis**, are predaceous on small longicorn larvae—including *Clytus*, *Epipedocera affinis* and *E. zona*, *Exocentrus alboguttatus*, *Ceresium leucosticticum*, *Kunbir telephoroides*, *Olenecamptus indianus*, *Xylotrechus smei*, *Xystrocera globosa* (Cerambycidae) and sometimes also on Bostrychidae. Beetles appear in June, July in north India or earlier in south India. The larvae of *Tenerus femoralis*, *T. quadrimaculatus* [fig. 75] and *T. signaticollis* are described in 1937, *tit. cit.*, pp. 38, 39, figs. 1–6. The aberrations of *T. signaticollis* and other species are described by Corporaal, 1939, *Ind. For. Rec.*, Ent. VI, No. 2.

Thanasimus himalayensis, prothorax black, elytra black with basal third red and 2 white transverse bands, length 12 mm., is predaceous as adult and larva on *Tetropium oreinum* (Cerambycidae) and on the Scolytidae of Himalayan conifers, e.g., *Blasto-*

phagus, *Ips*, *Polygraphus*, *Pityogenes*, *Scolytus*, also in the foothills on *Hylesinus javanus*. The larva is very similar to that of *Dasyceroclerus torulentus* and tunnels through the bark. The pupal chamber in the bark is lined with a silvery smooth layer; the life cycle is annual.

Thanasimus subscutellaris is predaceous on *Scolytus major*.

Thaneroclerus buquet is predaceous on *Lasioderma serricorne* (Anobiidae) in baled tobacco.

Tillodenops bimaculatus, a North African species, occurs in bored *Dendrocalamus strictus* and *Prosopis spicigera* in north-west India. The prey consists of Bostrychidae.

Tillus birmanicus is predaceous on dry-wood borers, i.e., *Lyctus africanus*, *Sinoxylon anale*, *S. birmanum*, *S. crassum* and *S. indicum*, *Heterobostrychus pileatus*, *Xylodectes ornatus* (Bostrychidae) and *Stromatium barbatum* (Cerambycidae). Emergence occurs in April–June with an annual life-cycle.

Tillus notatus. The colour-pattern of the beetle is widely variable and numerous "aberrations" have been named; head and pronotum red with a variable amount of black marking, elytra, black with basal quarter red and 2 yellow curved transverse bands, 8 to 13 mm. long. It is pre-eminently a predator of Bostrychidae and most commonly of the genera *Dinoderus*, *Lyctus*, *Trogoxylon*, *Sinoxylon*, and *Xylodectes ornatus*. The life-cycle is annual with a well marked emergence-period in March–June, although straggling emergences may occur throughout the year to October. The larva, 18 mm. long, is described by Gardner, 1937, *tit. cit.*, pp. 35, 36, fig. 11. The aberrations are described by Corporaal, 1939, *tit. cit.*, VI, No. 2, pp. 20–22.

Tillus succinctus, predaceous on *Dinoderus* (Bostrychidae). The larva, 20 mm. long, is described in 1937, *tit. cit.*, pp. 34, 35, figs. 7–10. [fig. 73, No. 10].

Tillus vicarius, predaceous on Anobiidae (*Ptilinus pectinicornis*). The larva, 15 mm. long, is described in 1937, *tit. cit.*, pp. 35, figs. 12–13.

Xenorthrius robustus, 12 mm. long, is associated with borers in *Acrocarpus fraxinifolius*, *Butea frondosa*, *Cedrela toona* and *Semecarpus anacardium*. The prey consists of small Cerambycidae and Buprestidae. [fig. 76].

COCCINELLIDAE

POPULAR names in many languages given to the COCCINELLIDAE suggest (says Balduf, 1935) their gentle nature and beneficent habits and express the affection and reverence in which these beetles are held by various peoples. In English they are usually known as 'Ladybirds' or 'Ladybird Beetles'. Because all stages live exposed and are easily observed, the ecology of the family is well studied; because the colours and patterns of the beetles are basically simple but in most species are very variable, the taxo-

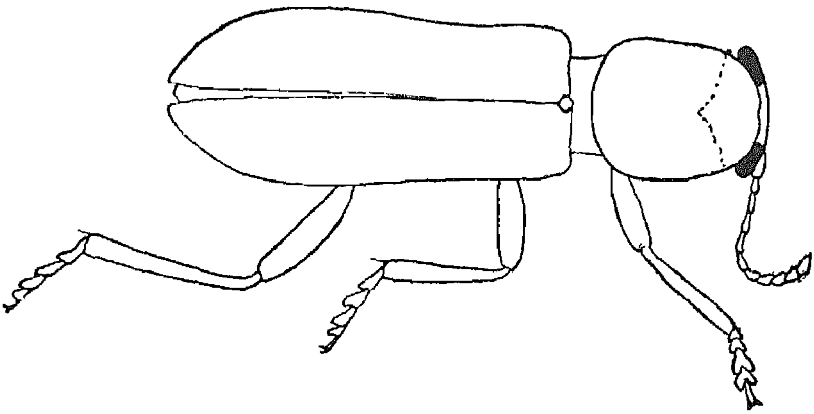

Fig. 76. Beetle of Xenorthrius robustus, Cleridae, natural size 12 mm.

nomy has attracted many workers—but the literature and catalogues are in several languages. In recent years Indian Coccinellidae have been determined by R. Korschefsky. Economically the species can be grouped as defoliators (Epilachninae) and predators (most sub-families); some of the Psylloborini are fungivorous.

Food: Coccinellid larvae largely eat the same kind of food and live in the same environment as the beetles. Although a species may be rated as predominently carnivorous or phytophagous it is not exclusively so; many predaceous species ingest varying amounts of plant-matter with the animal food and are able to subsist on the soft parts of plants when their prey becomes scarce, a qualification which increases their value as a natural control factor.

Defoliators and Predators: (i.) The defoliating species, e.g., *Epilachna*, lay eggs on leaves and the larvae feed on the surface-layers of cells, making a characteristic feeding-pattern of parallel scratched lines, each line being the scar or scrape of one bite of the mandibles. Pupation occurs in the split larval skin attached to the leaf. The life-cycle is often very short, about a fortnight.

(ii.) The predaceous groups feed as adults and larvae on plant lice and scale insects (Aphidae, Aleyrodidae, Coccidae), mites (Acarina), the eggs of other Coleoptera and Rhynchota. A beetle may eat more than 100 aphids a day and averages of 15 to 50 a day are normal. A single larva may dispose of 200 to 400 aphids; and if living in a cold climate with a long life-cycle a larva may eat 800 aphids or diaspine scales during the larval life.

Life-history: The elongate-oval yellow eggs are laid

vertically on end in clusters of a few to 50 in a cluster [fig. 78]. Fecundity is very high in some species, e.g., 1500 or over 20 eggs a day for a *Hippodamia*, 900 or 9 eggs per day for a *Leis* sp., 730 or 12 eggs per day for a *Coccinella*, while in others, e.g., *Chilocorus* it may be relatively low, 20 eggs per female, each of which is deposited under or alongside a scale insect. The egg-laying capacity of an individual or a species is to some extent dependent on the season, rising with increasing temperature, or on the quantity of food, rising with abundance of prey. Hatching of the egg always occurs in a short time, one to a few days. The larval stage lasts for a week to about 3 weeks, the pupal stage a few days, so that the total life-cycle takes, at its shortest, about 12-14 days, and at a slow rate about a month. In very few species is the life-cycle more prolonged ; the resting or hibernating stage is the adult beetle. There is a range of one to eleven generations annually in the Coccinellidae of the temperate and tropical regions.

Coccinellid larvae are campodeiform [see figs. 77, 78], elongate oval with bristles or spines and in some cases a powdery deposit or woolly filaments of wax. Most are active hunters searching for and attacking their prey even though larger than themselves ; but some live in the shelter of the immobile large prey ; some are myrmecophilous. Pupation takes place on leaves, stems and exposed places attached to the surface by the caudal end of the abdomen, usually head downwards. The larval or pupal skin is tough and defensively coloured [see figs. 77, 78].

Swarming: A characteristic of beetles of Coccinellidae is their gregariousness. Some of the commonest species assemble in countless numbers usually for hibernation, the cold season being passed in the adult stage; assemblage on a minor scale often occurs for pupation, or for migration, or for aestivation. There is a strong tendency for different species and varieties to segregate. The cause of this gregariousness has not been worked out but it may be the self-preservative reaction of a large active population deprived of its food-supply and of the urge to oviposit, but attracted together by characteristic odours and recognition marks which are specific and often varietal in their selective action.

Economically the Ladybirds are important for their utility and easy artificial exploitation as aids in biological control. Centuries ago rose-growers collected Ladybird Beetles and released them on rose-trees to clean up the blight. In the 1880's it was the phenomenal success of a Ladybird Beetle, *Rodolia cardinalis*, introduced to Californian citrus fruit orchards to clean up the fluted scale, that demonstrated the remarkable possibilities of biological control and set so high a standard for economic entomologists of the present century.

LITERATURE ON COCCINELLIDAE :

Aiyar T. V. R., 1925, *Journ. Bomb. Nat. Hist. Soc.*, xxx, pp. 491, 492, 1 pl., An undescribed coccinellid beetle of economic importance. Scymnus coccivora.

Chatterjee N. C. and Bose M., 1934, *Ind. For. Rec.*, XIX, vii, 10 pp., 4 figs., (17), Coccinellidae of sandal.
Corbett G. H. and Miller N. C. E., 1933, *Sci. Ser., Dept. Agr. S. S. and F. M. S.*, XIII, 15 pp., A list of insects with their parasites and predators in Malaya.
Dutt G. R., 1927, *Agr. Jl. India.*, XXII, pp. 291, 292, Aphids and ladybird beetles.
Korschefsky R., 1934, *Ind. For. Rec.*, XIX, vi, 9 pp., 1 pl., (16) Coccinellidae of sandal.
Pradhan S., 1930, *Journ. R. As. Soc. Beng.*, Sci., II, 2, The alimentary canal of Epilachna indica with a discussion on the activity of the mid-gut epithelium.
— 1938, *Rec. Ind. Mus.*, XL, iv, pp. 341-358, Neuromuscular study of the mouthparts of Coccinella septempunctata with a comparison of the mouthparts in carnivorous and herbivorous coccinellids.
Stebbing E. P., 1903, *Ind. Mus. Notes*, VI, pp. 47-62, pl. iii, Notes on the known predaceous Coccinellidae of the Indian Region, Part I.
— 1904, *Journ. Linn. Soc., Lond.*, XXIX, pp. 142-161, On the life-history of a new Monophlebus from India with a note on that of a Vedalia predacious on it.
Subramanyam T. V., 1925, *Journ. Bomb. Nat. Hist. Soc.*, XXX, pp. 924, 925, 1 pl., Coptosoma ostensum Dist. and its enemy Synia melanaria Muls.
— 1923, *Proc. 5th. Ent. Meet., Pusa*, pp. 108-118, Some coccinellids of South India.
Anon. 1919, *Agr. Res. Inst. Pusa*, Bull. 89, pp. 30, 31.

Adonia variegata, orange-yellow with black markings, variable in ab. *constellata*, *doubledayi*, etc., 4–7 mm. long, a widely distributed species, occuring upto 10,000 ft. in the Himalayas, preys upon Aphidae. The larva, 8 mm., is described by Stebbing (1903). "The larvae devour both wingless and winged forms. One grub watched, consumed seven aphids successively, springing upon the small insects, seizing and holding them with its anterior pair of legs and then sucking them dry. The skins are apparently swallowed as well... In the case of the winged forms the wings were the only portions rejected... The beetles run... quickly over the plant searching for aphids. Every little nook and cranny is visited... When an insect is discovered they seize and suck out the contents much in the same way and with the same voracious eagerness as the larva."

Stebbing E. P., 1903, *Ind. Mus. Notes*, VI, pp. 47-50 (as Hippodamia variegata var doubledayi and Hippodamia constellata).

Brumus suturalis, a yellow beetle with a black elytral suture, about 1/8th of an inch long, or with 3 black stripes, is in its larval and adult stages, an enemy of Coccidae, e.g., *Phenacoccus insolitus*, of Psyllidae, e.g., *Arytaina isitis* (nymphs), and of Aphidae. The elongate larva, 5 mm. long, is greyish in ground-colour with a fur-like covering of white wax. The life-cycle takes about three weeks.

Calvia tricolor is predaceous as larva and beetle on the eggs-masses of *Urostylis punctigera* (Pentatomidae).

Chilocorus bipustulatus feeds on Aphidae including the San Jose' scale in India.

Chilocorus circumdatus feeds on Coccidae including *Lecanium coffeae*.

Chilocorus nigritus, a purplish-black beetle, 1/4th of an inch long, is an enemy of Coccidae, e.g., *Aspidiotus destructor*, *A. orientalis*, *Chionaspis minor*, *Coccus viridis*, *Pulvinaria maxima*.

Eggs are laid under flakes of bark, or on the underside of leaves, and hatch in a week. The body of the larva bears long setose spines arising from tubercles; it moults three times and pupates in the split skin of the fourth instar attached to a leaf, etc. The complete life-cycle occupies about a month. About 150 scale insects may be eaten by one larva.

Coleman L. and Kunhikannan K., 1918, *Dept. Agr., Mysore*, Ent. Ser., Bull. 4, pp. 35–37.

Chilocorus politus feeds on Aphidae and and *Aspidiotus destructor*, *Ceroplastodes virescens*, *Diaspis bromeliae*, etc. (Coccidae). It has been introduced in 1937 from Java to Mauritius for the control of scale insects; its average life-cycle is 24 days.

Chilomenes sexmaculata, a widespread species, is a yellow beetle, 4–5 mm. long, with black spots or bands of variable shape and number which feeds on Coccidae, on Psyllidae, e.g., *Arytaina isitis*, *Phylloplecta* sp., on Aphidae and on Red Spider. The life-cycle may be completed quickly in 15 days.

Subramanyam T. V., 1923, *Proc. 5th Ent. Meet., Pusa*, p. 363, A note on colour variations.

Coccinella septempunctata, a widespread species, about 1/4 inch long, red with 7 black spots. This beetle and its larva feed on Coccidae, on Psyllidae, and on Aphidae, e.g., *Chermes himalayensis*. A larva may eat 8 aphids a day.

The genera **Epilachna** and **Solanophila** include species that feed on plants usually Curcurbitaceae and Solanaceae.

Epilachna dodecastigma. India to Java.

Life-history: The beetle is yellowish or reddish-brown, less than 2/5ths of an inch long, with 12 black spots on the elytra. Eggs are laid in clusters of 10 to 60 on the under surface of leaves of species of *Solanum* and of Curcurbitaceae. The oviposition-period lasts for several weeks (12) and as many as 800 eggs may be laid. Hatching occurs in 5–7 days. The larva is yellow with black-tipped serrate spines; it feeds by scraping away the surface-tissue of the leaf in closely adjacent patches leaving untouched narrow strips in between and a thin cuticle opposite, which turn brown. The beetles feed in the same way or may eat irregular holes. Badly attacked leaves have a lace-like appearance and shrivel and die. There are four larval instars in the course of about three weeks followed by pupation in the split skin of the 4th instar attached to the leaf. The pupal period lasts 5 to 8 days, giving a total life-cycle of 30 to 35 days. The beetles may live for six months through the cold weather.

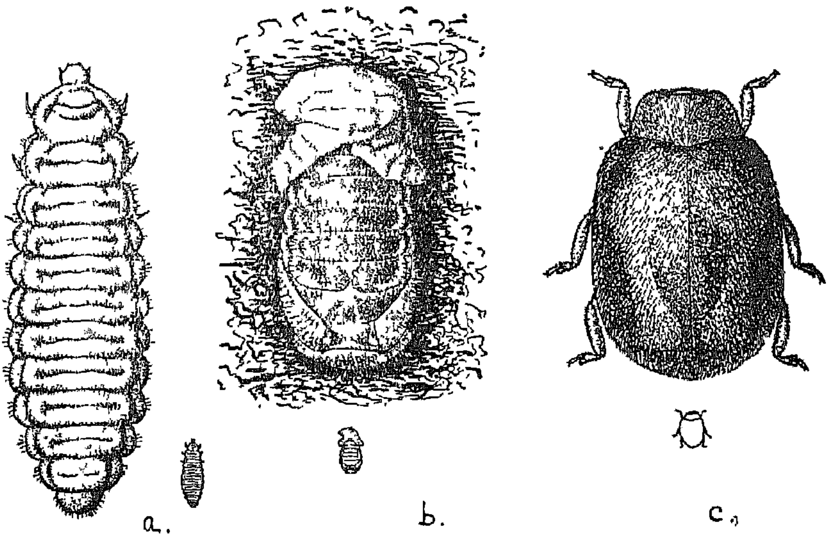

Fig. 77. Sumnius renardi, larva, pupa and beetle; natural size is shown by the small figures.

Epilachna ocellata, Himalayas to south India, feeds on *Solanum* sp.

Epilachna territa, India to Java, also a 12-spotted brownish ladybird beetle, feeds on *Solanum torvum.*

Epilachna viginti octopunctata, a widespread species, Japan, India to Australia, similar in colouring to the foregoing species, but with 28 black spots, defoliates wild and cultivated Solanaceae and Curcurbitaceae. It has a life-cycle of three to five weeks in south India and feeding-habits similar to those of *E. dodecastigma.*

LITERATURE:

Krishnamurti B., 1932. *Dept. Agr. Mysore,* Ent. Ser., Bull. 6, pp. 1–16. pl. i-v., The Potato Epilachna Beetle.
Shah S. A., 1939, *Punjab Agr. Dept., Seasonal Notes,* XVIII, pp. 34, 35 (control).
A coloured plate of the life-history, *Agr. Res. Inst.,* Pusa.

Halyzia sanscrita, defoliates *Dalbergia sissoo,* its larvae feeding on the epidermis of both sides. Pupation occurs on the leaf.

Ithone hexaspilota, a large beetle, 1/2 inch long, yellow or red with black cruciform markings and borders. The adult and its larva feed on the eggs and larvae of a species of Chrysomelidae defoliating *Salix alba.*

Nephus ? severini is predaceous on Coccidae on *Melia indica.*

Oenopia sauzeti is predaceous on Aphidae and *Arytaina* sp., *Psylla* sp. (Psyllidae).

Ortalia pusilla defoliates *Salix pentandra.*

Platynaspis lewisi is predaceous on *Euphalerus vittatus*. (Psyllidae).

Rodolia breviuscula is predaceous on *Icerya aegyptiaca* (Coccidae).

Rodolia cardinalis is predaceous on *Icerya purchasi*, the cottony cushion scale or fluted scale, and was originally introduced from Australia to control that pest in citrus fruit orchards in California. Since then it has been successfully utilised in many countries including Hawaii, Japan and New Zealand. It was introduced into India in 1929 to deal with *Icerya purchasi* in the Nilgiris where the scale had become a pest on *Acacia decurrens*, *A. dealbata* and other plants. Liberations in the Seychelles have failed to establish this species as a predator of *Icerya seychellarum*.

LITERATURE:

Rao Y R, 1930 *17th Ind. Sci. Congress*, Abstracts, Agr., p. 19. The biological control of the fluted scale.

Rodolia fumida, a widespread species, is predaceous as larva on the nymphs of *Drosicha stebbingii* (Coccidae).

Scymnus andrewesi coccivora, a small pale brown beetle, less than 2 mm. long, with 4 indistinct dark spots is predaceous on Coccidae, e.g., *Pulvinaria maxima*, *Pseudococcus virgatus*. The larva is greyish-green with long thick waxy processes. It feeds on the eggs of *P. maxima* often burying itself inside the egg-masses. The beetle feeds on the larvae of this scale insect of which it is an efficient factor in natural control.

Scymnus gracilis is predaceous on mites which live on foliage. The life-history is given by K. A. Rahman and A. N. Sapra, *Proc. 27th Ind. Sci. Congress*, iii, p. 177.

Sumnius renardi is predaceous on *Drosicha stebbingii octocaudata* (Coccidae) in all its stages. The larva is about 10 mm. long, light brown in colour without spines or tubercles, each body segment divided into 2 zones by a transverse furrow. It bites through the skin of the mealy bug and feeds on the yellow fluid in the body holding fast to its prey, which, if large, may carry the coccinellid about before succumbing, but otherwise makes no resistance. It is active from November to May and passes the intervening period as a resting beetle. [fig. 77 a, b, c, shows the larva, pupa and beetle].

LITERATURE:

Lefroy H. M., 1908, *Mem. Dept. Agr., Ind.*, II, No. 7, p. 117, (coloured figures) as Aulis vestita.

Hingston R. W. G, 1929, *Journ. Bomb. Nat. Hist. Soc.*, XXXIII, p. 886, fig. 2 (as Aulis vestita).

Anon. 1919, *Agr. Res. Inst. Pusa*, Bull. 89, pp. 29, 30, fig. 22.

Synia melanaria rougeti. The beetle has violet-black elytra and an orange thorax, length 3/8ths of an inch. The larva has been observed feeding on nymphs of *Coptosoma ostensum* (Subramanyam, 1925).

Thea bisoctonotata and **T. cincta** are common on leaves of

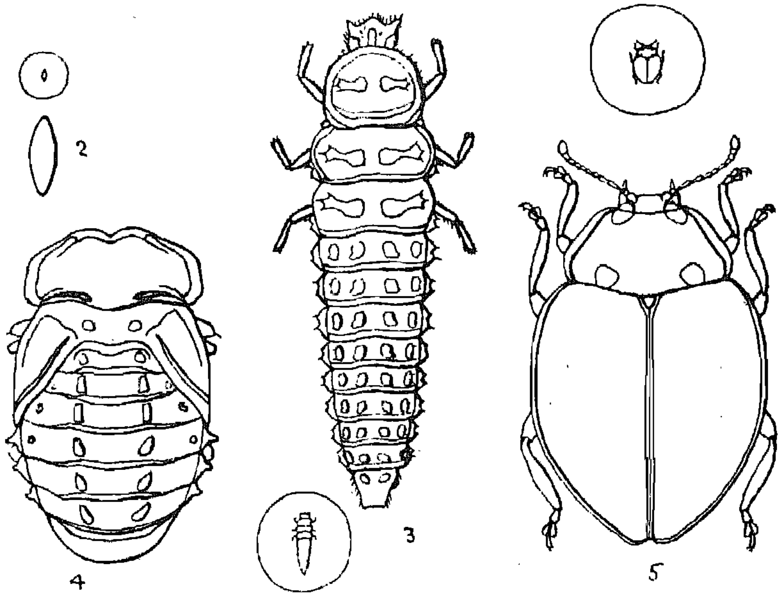

Fig. 78. Thea cincta, egg, larva, pupa and beetle ; natural size is shown by the small figures.

Dalbergia sissoo in the drier districts. The larvae are stated to eat the epidermis on both sides of the leaf which causes the attacked foliage to dry up and fall off. Pupation takes place attached to the leaf.

Thea cincta is predaceous on red spider *(Tetranychus)*. "The egg is dull-whitish, elongate, cigar-shaped, with a smooth surface and measures about 1 mm. in length. The grubs hatch out by bursting the free top ends longitudinally, the fissure extending downwards for about half the length of the egg. The newly-hatched grub is about 1·5 mm. in length, flattened, the segments distinct, in colour pale yellow with a blackish spot on each side of the head and a black subdorsal spot on all the thoracic and abdominal segments except the anal segment which has a black plate. The thoracic legs are long and well-developed and the young grub is very active.

The full-grown larva is about 9 mm. long, and similar in shape and general colour to the young grub but is tinged with yellow dorsally and has a median black marking on the head, the black thoracic spots are transversely elongated, and there is also an additional row of dorsolateral black spots on all abdominal segments except anal.

Pupation takes place on a leaf or stem. The pupa, which is about 5 mm. long and 3 mm. broad, is pale-yellow with irregular deeper yellow dorsal patches, four black markings on posterior edge of pronotum, and the margins of wing-sheaths black, and a subdorsal black spot on first six abdominal segments." [see fig. 78, 1-5].

LITERATURE:

Anon. 1916, *Agr. Res. Inst.*, Pusa, Bull. 59, pp. 14, 15, fig. 7, Early stages of Thea cincta.

Vedalia guerini.

The beetle is about 1/4 of an inch long, dark reddish-brown with six black spots. The larva is black when young and light reddish or purplish in the last stage.

Life-history: The eggs are laid on the twigs or leaves of *Shorea robusta* and other trees on which the mealy bug, *Drosicha stebbingii* (Coccidae), feeds. The larva may travel considerable distances with great rapidity in search of its prey.

In attacking a nymph or female of *Drosicha* the coccinellid larva bites a hole in the skin in which its jaws are then firmly embedded. The body of the bug is also clasped by its fore-legs, but its mid and hind legs are scarcely used, anchorage to the twig or leaf being obtained by the sucker at the extremity of its abdomen. The coccinellid is able to retain its position in spite of the struggles of the much larger prey, which may continue for several hours before the mealy bug succumbs. Much of the abundant, yellow fluid in the body of the mealy bug is spilled, but the quantity absorbed and rapidly digested by the coccinellid is very high and eventually the *Drosicha* is reduced to an empty skin. The beetle also feeds on the mealy bug at punctures in the skin, but only for a short period up to half an hour, and without apparently weakening the bug. Individuals which have been punctured several times show small white or yellow scars and the body is appreciably shrunken.

Pupation by *V. guerini* is generally gregarious on twigs and leaves, each crimson pupa in the split skin of the 4th instar, which is attached by means of its sucker. The beetles collect in clusters during the hotter part of the day.

Importance: This species is an important natural enemy of *D. stebbingii* in the sal forests of north India. Stebbing describes the conditions in 1902 . . . "The forests were a truly remarkable sight about the middle of April. Larvae, pupae, and adults of the *Vedalia* were everywhere; the former running agilely over the trees in quest of their prey; the pupae being collected in numbers on leaves and twigs, more especially perhaps on the former; whilst the large leaves of the trees were weighed down by the red masses of the beetles clinging to their under surfaces during the heat of the day, as these latter only feed in

the early morning and evening. On every side also were dried shrivelled skins of the sucked-out scales, gummed to the branches or bark of the trees, stuck in the interstices of the bark of the latter or littering the ground amongst the dead leaves, etc. Away aloft the crowns of the great sal trees appeared to have their extremities encrusted with snow from the numbers of the scales clinging to and feeding on the sap of their twigs and smaller branches, and this incrustation was repeated on the branches of smaller trees and saplings, whilst the crawling coccids invaded every corner of ones' tent and covered the leaf littered ground without."

LITERATURE:

Stebbing E. P., 1904, *Journ. Linn. Soc.*, Lond., XXIX, pp. 142-161, On the life-history of a new Monophlebus from India with a note on that of a Vedalia predaceous on it.

COLYDIIDAE

THE family of COLYDIIDAE are clavicorn beetles of variable form and sculpture found under loose bark and in the tunnels of wood-borers on which they are predaceous. Some are oval and convex, others are elongate and cylindrical with similar modifications of the body, particularly of the elytral declivity, to those characteristic of Brenthidae and Platypodidae; the cylindrical forms are specifically predators in open cylindrical tunnels. Practically nothing is known of their effectiveness as natural checks. These beetles are often erroneously taken for the real wood-borers; they are not entirely carnivorous and are able to subsist to some extent on decaying bark and sapwood.

There is no monograph or catalogue in Indian literature. Collections were named and described by A. Grouvelle and G. C. Champion.

Bitoma siccana, a very common species found in association with wood-borers of all families throughout the Indian region. Beetles escape from the wood at any time of year but most abundantly in July–August.

Bothrideres andrewesi and **Pseudobothrides velatus** are predaceous on Bostrychidae, *Sinoxylon* spp., *Xylodectes*, etc. They also occur in association with larvae of Buprestidae, Cerambycidae, Curculionidae and Scolytidae in bored wood. It would be more correct to regard a *Bothrideres* larva as a parasite, for one host larva is sufficient for its sustenance and may support more than one *Bothrideres* larva. The host is killed after it has constructed its complete tunnel or pupal chamber and the *Bothrideres* pupates in the host's tunnel in a cocoon of a chitinous material. Emergence occurs from June to November, mainly in June.

Cebia rugosa occurs under the bark of trees attacked by Scolytidae, Platypodidae, Cerambycidae, etc.

Colobicus parilis is predaceous on bark beetles (Scolytidae) and sapwood borers of various families. The emergence-period is extended from April to December.

Dastarcus indicus, 8 mm., and **Trachypholis hispida,** 6 mm., and allied species of oval convex forms are common in bark associated with bark-borers.

Dastarcus porosus occurs in wood bored by Cerambycidae; it preys on *Rhytidodera simulans* (Cerambycidae).

Corbett G. H. and Miller N. C. E., 1933, *Dept. Agr., S. S. and F. M. S., Sci. Ser*, XIII, pp. 15.

Microprius spp and **Ocholissa** spp. occur in association with Bostrychidae, Curculionidae and Scolytidae in bark and sapwood.

Nematidium spp. are elongate cylindrical beetles predaceous in the tunnels of shothole-borers, *Xyleborus* (Scolytidae) and Platypodidae. Like their hosts the beetles are characterised by sculptural and structural modifications of the elytral declivity which serve in clearing obstructions from the tunnel.

Teredolaemus major is predaceous on Scolytidae of conifers in the Himalayas.

Teredolaemus unicolor occurs with bark-borers in south Indian trees.

Xuthia see **Bitoma.**

CUCUJIDAE

BEETLES of the clavicorn family CUCUJIDAE are large to minute and rather delicate forms most often found under loose bark and in the tunnels of wood-borers. The body of the beetle is characteristically elongate and flattened, but the larvae include flattened and more or less cylindrical forms. Small cucujids may be confused with Lyctus beetles. The following habits are represented—(a) true predators on wood-borers, (b) scavengers in the galleries of wood-borers, (c) feeders on flour, grain, dried fruit and other vegetable diet.

One can judge the economic importance of a predaceous species of Cucujidae only by its numbers, as life-histories have not been studied. The Indian species were monographed and mostly described by Grouvelle, but there is no monograph or catalogue in Indian literature.

LITERATURE ON CUCUJIDAE:

Gravely F. H., 1915, *Rec. Ind. Mus.*, XI, pp. 353-358, pl. xxi, figs, 13-19, The larvae and pupae of some beetles from Cochin (Literature on cucujid larvae).

— 1916, *tit. cit.*, XII, pp. 150, 151, pl. xxii, figs. 18-22, Lignicolous beetle-larvae.

Cathartus advena, 2 mm., widely distributed species, occurs in stored lac and grain and in seeds attacked by Scolytidae. Stebbing, 1914, p. 120, calls this species a 'teak leaf gall maker'; the gall is actually made by a species of Cecidomyidae.

See also Imms A. D. and Chatterjee N. C., 1915, *Ind. For. Mem.*, p. 37, pl. VII, fig. 28 (Silvanus advena).

Cucujus bicolor, 10 mm., black with red elytra, occurs under bark of conifers and oaks in the Himalayas, and is predaceous on Scolytidae.

Hectarthrum depressum, H. heros and **H. trigeminum** shining black, 12–15 mm. long, unusually robust cucujids, which occur in numerous species of trees throughout India, as predators of small larvae of Cerambycidae, Curculionidae and of Bostrychidae, etc. Beetles mature between March and November but mainly in August. The larva of *H. trigeminum* is described by Gravely, 1916, as a predator of *Mecistocerus* (Curculionidae). It has a modified barrel-shaped body with reduced legs and mandibles indicating a semi-parasitic habit.

Laemophloeus. Several species occur in the galleries of small bark-boring Scolytidae where they are predaceous. The life-cycle is probably short,—5 weeks to 2½ months,—but the beetle is long-lived.

Laemotmetus insignis, reddish-brown, 8 mm., is a predator associated with many genera of Bostrychidae including *Dinoderus* and *Lyctus*. Emergence occurs in March–October, mainly in June, July.

Laemotmetus rhizophagoides occurs in association with *Dinoderus* and lyctids. The emergence-period may be prolonged up to 4 years in bamboos and canes attacked by Bostrychidae.

Oryzaephilus surinamensis. The Sawtoothed Grain Beetle, a worldwide pest of stored grain, flour, dry fruits, oil cake, occurs in forests in dry or decaying vegetable matter such as seeds of trees, dry twigs, pine needles attacked by scale insects, bored bark, etc. The life-cycle in flour in India may be completed in 7 weeks; emergence from bark continues throughout the year.

Platycotylus spinicollis. Another species occurring in sapwood bored by Anobiidae and Cerambycidae.

Prostomis morsitans lives in colonies of beetles and larvae of various ages in rotten wood.

Protosilvanus lateritius. A common species breeding under bored bark with Scolytidae; beetles occur at all times of year without definite period of maximum emergence.

CURCULIONIDAE

WEEVILS make a multitudinous assemblage that is probably the largest natural family in the Animal Kingdom. There are perhaps 4,000 species of CURCULIONIDAE already recorded from the Indian region out of the quarter of a million species in the whole world. Weevils are ordinarily recognisable in the adult stage by the snout-like prolongation of the head in front of the eyes into a rostrum at the end of which are the mouth-parts. This rostrum varies immensely in its shape,—from a short broad muzzle to a long

slender rod-like weapon; with this variation in form there is a diversity of function in the acts of feeding, egg-laying, preparation of the larval home, etc. For a general account of the morphology, habits and classification of the family G. A. K. Marshall's introduction to the Curculionidae in the *Fauna of British India* (1916) should be consulted. Marshall, Heller and Voss are responsible for most of the taxonomic work that has been done on the Oriental weevils during the past quarter of a century and for the description of new species from the Indian region.

Beetles: As a whole the colouring of weevils is of distinctly sombre greys and browns; gayer colours and patterns are due to a scaly covering. In spite of this general tendency to sobriety in colour the Curculionidae have produced some of the most beautiful creatures in the insect world, e.g., the bejewelled *Cratopus* peculiar to the islands of the Indian Ocean. In size curculionid beetles vary from about a millimetre to over 2 inches with a corresponding size-range in the larvae: from which is to be expected considerable variety in the nature and extent of the damage that can be done to plants by weevils.

Larvae: In his work Marshall stated that "despite their undoubted economic importance, extremely little is known about the early stages of Indian Curculionidae, and, indeed, this applies to the family as a whole; for even in Europe and North America, where alone the subject has received any considerable attention the species whose larvae and pupae have been described form a very small percentage of the whole". Since then Gardner has studied and described the larvae of many Indian species (1934, 1938) and has characterised generic groups and subfamilies.

Feeding habits: As far as is known differences in larval habits universally characterise the two subdivisions of the family; the larvae of the Adelognathi live freely in the soil, feeding on roots—the larvae of the Phanerognathi are internal feeders in plant-tissues (the great majority) or are external feeders on exposed parts of plants (Gardner). With rare exceptions the whole family is phytophagous. In 1914 Stebbing recorded 40 identified species of forest Curculionidae of which the food or feeding-habit was known. It is now possible to record the food-plants of 270 species of Indian Curculionidae and to base a convenient classification of damage according to the parts of the plant affected.

Synopsis of damage to plants by Curculionidae.

(1) FLOWERS AND FRUITS.

(a) Flowers and floral buds—

The beetles of many genera eat flowers. The larval life of some species of *Apion*, *Larinus*, *Mecysmoderes* is completed in flowers.

(b) Fruits and seeds—

In many genera the egg is laid on the young fruit and the

larva feeds within the seed or the enveloping tissues and usually pupates therein, e.g., some species of *Alcides, Balaninus, Baris, Calandra, Cryptorrhynchus, Dicranognathus, Kozubo, Nanophyes.*

(2) FOLIAGE.

(c) Defoliators—

(i) The beetles of many genera are defoliators feeding directly on the leaves of the plant, e.g., *Astycus, Brachyxystus, Myllocerus.* The beetles of some species work in migrating swarms. The larvae of this group constitute most of group 4 (i).

(ii) The larvae feed externally on leaves in *Cionus, Coniatus, Hypera.*

(d) Leaf-rollers—

The leaf-rolling beetles are classed in the Rhynchitinae, *Apoderus, Attelabus, Deporaus, Henicolabus.*

The female prepares a leaf by cutting its veins or midrib and rolling it up in a particular way so that healthy sappy tissue withers under conditions favorable for the development of the larva; an egg is laid inside the rolled leaf and the larva feeds within the shelter of the roll and pupates therein or in the soil. This highly developed instinct is owned by the female alone and is coupled with special modification of the female rostrum which is always longer than that of the male. Some species roll the leaf without cutting it previously but most make a transverse cut severing the midrib. *Deporaus* rolls the leaf longitudinally; *Apoderus*, and *Henicolabus* roll the leaf transversely [fig. 80, see also *Apoderus (Strigapoderus) sissu*].

(e) Leaf-miners—

The larva mines between the upper and lower epidermis layers, e.g., *Rhynchaenus.*

(3) WOOD AND PHLOEM.

(f) Shoot-borers and Stem-borers—

(i) The true shoot-borer lays the egg in the living shoot in various devices such as pits, slits, notches or girdles. The shoot may be herbaceous and soft, or woody with bark. The larva bores a tunnel or chamber in the pith and succulent green tissues, or in the hard and woody tissues. Pupation is usually in the tunnel but may be in soil or other sheltering material, e.g., *Alcides, Calandra, Chelothippia, Cyrtotrachelus, Lixus, Lobotrachelus, Trigonocolus.*

(ii) Stem-borers exhibit similar habits. They are often gall-formers owing to reaction of the growing plant to a short localised larval gallery or feeding-chamber; the stem swells on its whole circumference or a more restricted and shaped gall is formed, e.g., some species of *Alcides, Baris, Gymnetron, Nanophyes, Pachyonyx.*

(g) Collar-borers—

A specialised form of attack by a species such as *Plagio-*

phloeus longiclavis is concentrated at the base of the stem at the collar and just above ground-level or extends to the rootstock.

(h) Wood-borers—

As with wood-borers of other coleopterous families all types of gallery-system are represented, viz. (a) the true bark-borer with the larval and pupal burrows confined to bark, (b) sapwood-borer with larval tunnel grooving the sapwood and the pupal cell within its depth avoiding heartwood, (c) deep borers passing throughout undifferentiated softwood, e.g., *Mecistocerus*, *Rhadinomerus*, *Sipalus*.

(4) ROOTS.

(i) Soil-dwellers—

A large group, practically the whole of the Adelognathi, the larvae of which live in the soil and feed on rootlets of living plants, or on dead plants or on humus and decayed vegetable matter in soil. The egg may be laid on leaf and the hatched larva drops to the ground (*Episomus*) or the egg is deposited in soil or the food-substance. The beetles of this group constitute most of group 2 (c), e.g., *Amblyrrhinus, Astycus, Myllocerus, Sympiezomias*, *Tanymecus*.

Economic importance: The borers of living saplings and yearlings are the most important pests of forests in India, e.g., *Alcides* species affect the leading shoots of several species of trees. *Pagiophloeus longiclavis* is a serious obstacle to pure planting of mahogany. *Cyrtotrachelus* species are locally bad pests of sprouting bamboo culms. Among the wood-borers *Sipalus hypocrita* makes the largest and most extensive tunnels. The grain weevils are cosmopolitan pests; *Calandra oryzae* occurs in every Indian household.

Life-cycle: The length of the life-cycle of Curculionidae shows considerable variation, and probably a greater variety of types of annual sequence of generations than in any other family; this is due to the range of habitat and food which are utilised by free-living mobile stages, soil-dwellers and wood-borers. The shortest life-cycle recorded in India is 10 days; the longest is one year and this period does not seem to be exceeded normally by wood-boring species. The longer cycles are due either to a long larval stage or to a prolonged adult life which may be partly dormant or inactive in shelter.

The life-cycles of India Curculionidae may be alloted to six main groups based on the minimum length of the generation; types attacking living plants are indicated separately from those attacking dead plant-tissue. (Compare Cerambycidae, page 131.)

Synopsis of generations of Curculionidae

(1) GENERATION LESS THAN ONE YEAR

(The periods given in brackets are for the shortest life-cycle)

(a) ABOUT 8 GENERATIONS A YEAR

Leaf-rollers—
Apoderus sissu (10 days)
Leaf miners—
Rhynchaenus mangiferae (10 days)

(b) ABOUT 5 GENERATIONS A YEAR

Soil-dwellers—
Myllocerus 11-pustulatus (35 days)
Living palm borer—
Rhynchophorus ferrugineus (50 days)

(c) 3 GENERATIONS A YEAR

Living shoot or stem-borers—
Alcides affaber (55 days)
Cryptorrhynchus rufescens (75 days.)

(d) 2 GENERATIONS A YEAR

Dead wood-borers—
Species of *Camptorrhinus*, *Rhadinomerus*
Seed-borers—
Calandra glandium

(2) GENERATION ANNUAL

Wood-borers—prolonged larval stage
Mecistocerus spp., *Hylobius*, *Phaenomerus* spp., *Phloeophagosoma*
Living shoot-borers—prolonged beetle stage
Alcides gmelinae, *Cyrtotrachelus* spp.
Fruit-borers—prolonged beetle stage
Alcides porrectirostris

(3) GENERATION ANNUAL BUT LIABLE TO BE PROLONGED

Dead wood-borers—
Cossonus spp., *Mecistocerus fumosus*, *Xenomimetes*

No observations have been made on the variation in the length of the generation and their number within the habitat of a species.

LITERATURE ON CURCULIONIDAE:

Ayyar, T. V. R., 1922, *Agr. Res. Inst., Pusa*, Bull. 125, pp. 21, pls. XX, The weevil fauna of south India with special reference to species of economic importance.

Fletcher, T. B., 1919, *Rep. Proc. Third Ent. Meet., Pusa*, pp. 185-212, Annotated list of Indian crop pests.

Gardner, 1933, Stylops, II, pp. 81-85, The early stages of two Indian weevils.

— 1934, *Ind. For. Rec.*, XX, ii, pp 1-42, 6 pls., Immature stages of Indian Coleoptera, (14) Curculionidae,

— 1938, *tit. cit.*, Ent., III, No. 12, pp. 227-26, 6 pl., *ibid*, (24) Curculionidae contd.

Marshall, G. K., 1916, *Fauna Brit. Ind.*, Coleoptera, Curculionidae, 1, pp. 367, figs. 108.

— 1931, *Ind. For. Rec.*, XVI, VIII, pp. 263-278, figs. 10, New Indian Curculionidae

— 1936, *Ind. For. Rec.*, Ent., I, No. 11, pp. 205-231, New Indian Curculionidae.

— 1938, *tit. cit.*, III, No. 9, pp. 159-184, figs. 6, New Indian Curculionidae.
Stebbing, E. P., 1914. *Ind. For. Ins.*, pp. 393-456, figs. 264-301, pl. xxviii-xxxviii.
Voss E., 1935. *Ind. For. Rec.*, Ent., I, No. 5, pp. 95-104, Neue Attelabiden aus Indien.

Acicnemis arcufera bores the wood of *Artocarpus nobilis* and *Hibiscus tiliaceus*. Emergence occurs in March, April.

Acicnemis bauhiniae bores the wood of *Bauhinia vahlii*, *Dalbergia sissoo* and *Michelia champaca.*

Acicnemis exclusa bores the wood of *Albizzia odoratissima.*

Acicnemis mansueta bores *Artocarpus nobilis* and *Hibiscus tiliaceus.*

Acicnemis praeambulans bores *Erythrina indica.*

Aclees birmanus bores the wood of *Ficus religiosa;* the larva is described by Gardner, 1938, *Ind. For. Rec.*, Ent., III, No. 12, pp. 234, 235, fig. 42.

Aclees cribratus bores the wood of *Ficus carica.*

Acythopeus bispinosus bores the wood of *Vallaris heynei;* the larva is described in 1938, *tit cit.*, p. 239, fig. 53.

Agametis rosea bores the wood of *Neonauclea griffithi.* The larva, 17 mm. long, is described in 1938, *tit. cit.*, pp. 240, 241, figs. 27-29.

The genus **Alcides** consists of elongate or stout coarsely sculptured weevils with long rostra and legs, usually dark brown in colour; the larvae are borers of young living shoots and of fruits. A key to larval characterstics of 9 species is given in 1938, *tit. cit.*, pp. 242, 243.

Alcides affaber, a yellowish-brown species, about 3/8ths of an inch long, [fig. 79] injures living shoots of *Althea rosea*, *Bombax malabaricum*, *Chorisia crispifolia*, *Ficus bengalensis*, *Hibiscus cannabinus*, *H. esculentus*, *H. mutabilis*, *H. rosa-sinensis*, *Kydia calycina* and *Urena lobata.* The new growth at the beginning of the rains is punctured by the beetle, mainly for feeding, and the shoot dies back above the wound. Eggs are laid in similar punctures and the larva tunnels down the pith for several inches making small holes for the ejection of fragments of plant-tissue mixed with excrement and sap. Pupation occurs in the tunnel. The brood commencing in July matures in 8 weeks or less and another commences in September. The shoots die back to the old wood. The larva, 12 mm. long, is described by Gardner, 1934, *Ind. For. Rec.*, XX, ii, p. 29, figs. 53, 54.

Alcides bubo attacks *Indigofera* spp. and *Sesbania grandiflora*, the larva boring the green shoots and causing a slight swelling. The larva is described by Gardner, 1934, *tit. cit.* p. 29. A coloured plate of the life-history has been issued by the Agricultural Research Institute, Pusa (Ayyar 1921).

Alcides crassus is a large chestnut-brown broad-bodied species [fig. 4, No. 22] which feeds as larva (length 20 mm., width 7 mm.)

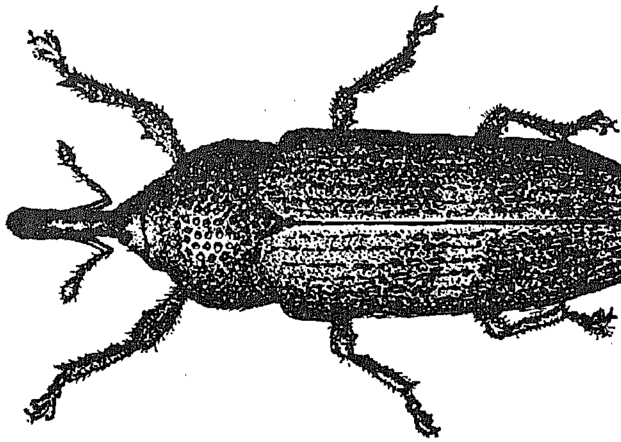

Fig. 79. Beetle of Alcides affaber, natural size 10 mm.

in the fruits of *Dipterocarpus grandiflorus, D. pilosus, D.trinervis, D. turbinatus, Hopea acuminata, Shorea* spp.; it destroys seeds so extensively as to affect regeneration. The larva is described in 1934, *tit. cit.*, p. 28, figs. 55, 56. It is a pest in the Philippines, Java, and Burma.

Alcides dipterocarpi is a smaller species attacking the seeds of *Dipterocarpus tuberculatus* and *Pentacme suavis.* The larva 12 mm., is described in 1938, *Ind. For. Rec.*, Ent., III, No. 12, pp. 245, 246.

Alcides feae makes swollen galls in the stem of *Clerodendron infortunatum.* The larva is described in 1938, *tit. cit.*, p. 245.

Alcides frenatus attacks *Mangifera indica* shoots.

Alcides gmelinae. This beetle (an elongate cylindrical black species about 3/8ths of an inch long) [fig. 4, No. 18], attacks the young green shoots of *Buddleia madagascarensis* and *Gmelina arborea* from Dehra Dun to Burma. The female gnaws a vertical series of cells in the pith of the shoot of *Gmelina arborea*; the fissure over the site of the cells is closed by the frayed-out woody fibres. One yellow egg is laid in each cell. The larva bores down the centre of the shoot, making small holes through the bark at intervals for the ejection of dust and excrement which is extruded in long pendent cylinders. The larva, about 15 mm. × 2 mm. when fullgrown, pupates near the bottom of the tunnel and the adult emerges by a circular hole. The life-cycle is apparently annual, the beetles appearing in August, September and remaining alive throughout the winter and spring. The larva is described by Gardner, 1934, *Ind. For. Rec.*, XX, ii, pp. 28, 29, fig. 57.

E c o n o m i c i m p o r t a n c e: The tunneling of the shoot may

cause it to die back for several feet; new shoots are sent out by the nearest living buds. Sometimes globular swellings are produced on branches where the eggs or young larvae have died off. The year-old branches are not attacked. Heavy attacks produce bushy crowns and height-growth ceases.

Alcides ludificator is a weevil of similar appearance and habits to *A. gmelinae* but attacks *Tectona grandis* saplings. The tunnel is often carried down from the green shoot into the older woody portion of the stem but is confined to its pith. The beetles feed by making longitudinal punctures with the rostrum in the thick midrib and petiole of the teak leaf. It is one but not the chief of the causes of dying-back of leaders of teak saplings.

Alcides mali bores the shoots of *Pyrus malus* causing a gall-like swelling.

Alcides micronychus, a dark weevil with a prominent transverse white band near the apex of the elytra, breeds in the winged fruits of the creeper *Dioscorea belophylla.* The larva is described in *Ind. For. Rec.*, Ent., III, No. 12, p. 243, fig. 22.

Alcides porrectirostris, an elongate-oval black weevil, is a pest of walnuts (fruits of *Juglans regia*). The adult hibernates under stones, in crevices, etc. until March. The eggs are laid from April onwards in incisions in the pericarp of the young developing fruit; 4 to 8 larvae may develop within a single fruit feeding on the endocarp and kernel. The life-cycle is completed in 6–9 weeks but the generation is annual. The attacked fruits become deformed or fall prematurely in May, June. The larva is described in *tit. cit.*, p. 245, figs. 25, 26.

Alcides satellus is a borer of living shoots of *Leea sambucina*.

Alcides scenicus bores the green shoots of *Anisomeles;* the beetle punctures the ribs and stalks of teak leaves.

Alcides westermanni is a borer of stems of *Ficus religiosa, Rumex* and *Impatiens.* It occurs at high elevations, (up to 7,000 ft.) in the Himalayas. The larva is described in *tit. cit.*, pp. 244, 245, fig. 23.

Amblyrrhinus poricollis. The beetle feeds on the foliage of *Aegle marmelos, Albizzia lebbek, Casuarina equisetifolia, Dalbergia sissoo, Mangifera indica, Nephelium litchi, Terminalia* spp. and *Zizyphus jujuba.* The larva [fig. 83] lives in the soil and feeds on rootlets of the same species. It is described in *tit. cit.*, p. 231, figs. 80, 81. It is rated as a pest of seedlings of *Casuarina equisetifolia.*

Amblyrrhinus subrecticollis bores *Mallotus philippinensis.*

Amphialus turgidus. The larva bores the wood of *Calophyllum walkeri, Cupressus lawsoniana, Pinus longifolia* and *P. patula* in Ceylon: the choice of exotics as food-plants suggests the species will be found to be strongly polyphagous. The life-cycle is annual with emergence in March, April. The larva,

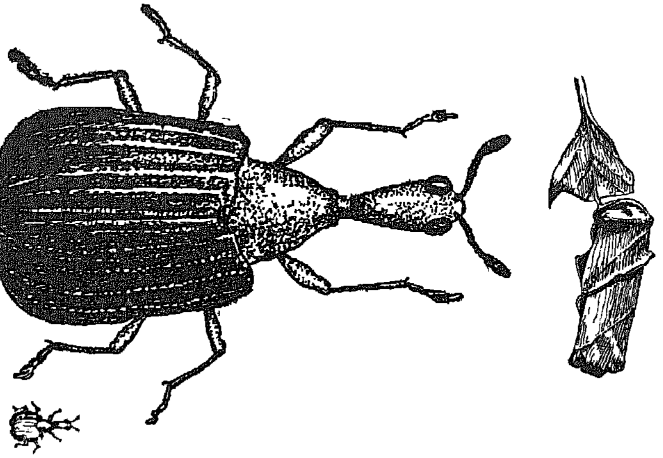

Fig. 80. Beetle of Apoderus picinus. Leaf rolled by Apoderus blandus.

length 13 mm., is described in *tit. cit.*, p. 250, figs. 12-14.

Anisus pauperatus. The larva bores the wood of *Amoora wallichi*, *Castanopsis* sp., *Elaeocarpus* sp., and *Phoebe lanceolata*. Emergence occurs in November, December. The larva, 5 mm. long, [fig. 83] is described in *tit. cit.*, pp. 253, 254, figs. 65-71.

The genus **Apoderus** forms a group of leaf-rolling species, the beetles of which have the habit in common of cutting a leaf across near its base so as to sever the midrib, and of rolling up the partially detached part of the leaf so as to form a cylindrical roll or packet in which the egg is laid and the larva feeds. [fig. 80]. The rolls usually drop to the ground and enable the larva to pupate in the soil. The genus has been divided into various subgenera considered by some authorities as genera, e.g., *Hoplapoderus*, *Leptapoderus*, *Paracycnotrachelus*, *Paroplapoderus*, *Strigapoderus*, *Trachelophorus*.

Apoderus (Paroplapoderus) bihumeratus, beetle yellow with several black spots, 4 of which on the elytra are spined; it is a leaf-roller of *Quercus incana* and also occurs on *Alnus nepalensis*.

Apoderus (Leptapoderus) blandus is a leaf roller of *Dalbergia sissoo* and *Terminalia* spp. The beetle closely resembles *A. picinus*. [fig. 80 shows the beetle and a rolled leaf.]

Apoderus (Leptapoderus) bistriolatus, about ¼ of an inch long, light brown or testaceous with a black spot near the base of each elytron, is a leaf-roller of *Juglans regia*, *Prunus padus*, *Quercus dilatata*, *Q. incana*.

Stebbing, 1914, *Ind. For. Ins.*, pp. 416-418, fig. 281 (as *Apoderus incana*).

Apoderus (Trachelophorus) brachmanus occurs on *Alnus nepalensis*.

Apoderus (Paracycnotrachelus) cygneus, reddish-brown, the head dark; the male is remarkable for the very much elongated head and pronotum. The beetle rolls the leaves of *Cleistanthus collinus*, *Xylia dolabriformis* (seedlings).

Apoderus (Allapoderus) dentipes, a bluish-black beetle, eats the young leaves of *Desmodium sambuense* and *Pieris ovalifolia* and rolls the leaves of *Desmodium* and *Quercus dilatata*.

Apoderus (Hoplapoderus) gemmatus, yellow with black spots most of which are tuberculate, rolls the leaves of *Ougeinia dalbergioides* and *Sida rhombifolia* var. *obovata*. The larva is described by Gardner, 1934, *Ind. For. Rec.*, XX, ii, p. 7.

Apoderus (Hoplapoderus) hystrix. The form **echinatus**, 7 mm. [fig. 81 shows the beetle] is a leaf-roller of *Helicteres isora* and *Xylia dolabriformis*, particularly seedlings of *X. dolabriformis*. The form **hystrix** rolls the leaves of *Sterculia villosa*. The larva, length 8 mm., is described by Gardner, 1934, *Ind. For. Rec.*, XX, ii, p. 7, fig. 8.

Apoderus luteibasis rolls the leaf of *Eugenia jambolana*.

Apoderus picinus, 4 mm., rolls the leaves of *Terminalia* spp. [fig. 80].

Apoderus (Strigapoderus) sissu, leaf-roller of *Dalbergia sissoo*.

Beetle, testaceous or golden yellow with a dark suffusion and three black spots on the elytron, 1/6th to 1/4 inch. Egg, smooth, creamy white, oblong, 1 mm.. Larva, legless, wrinkled curved, white or yellowish, full size 5 mm. Pupa, white to dark brown, body with a sparse covering of bristles and 2 spines at the abdominal apex, 4·8 mm. by 2·7 mm.

The shisham leaf-roller is often abundant enough to destroy the entire flush of new leaves, either by rolling them up or by cutting through the midrib. Recorded from the Punjab, United Provinces and north Bihar but possibly widely distributed.

L i f e - h i s t o r y: The beetles frequent the foliage of *Dalbergia sissoo* but are very active and drop to the ground when approached: in consequence they are not noticed unless carefully searched for. The female constructs the roll by biting across the leaf-blade near the base from the opposite edges up the midrib thus dividing the blade into two unequal portions; sometimes the leaf is cut from one edge right through the midrib to near the other edge. The opposite halves of the leaf are gripped by the jaws and legs and folded longitudinally along the midrib; the upper surface is always turned inwards. It is then made fast by tucking in the tip. A small cavity is bitten in the midrib and an egg inserted. The rolling is continued up to the transverse cut until a compact cylindrical packet is formed, an operation which takes about three-quarters of an hour. The roll remains suspended from the petiole for a while or falls at once.

The egg hatches in 3 to 6 days during March-September and

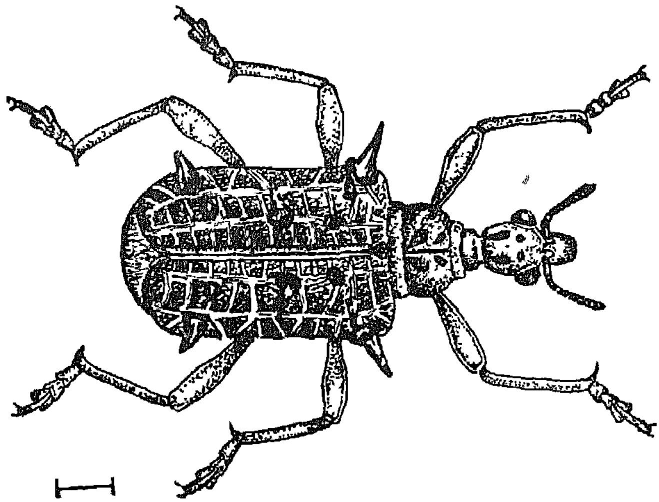

Fig. 81. Apoderus (Holapoderus) hystrix f. echinatus, natural size 7 mm.

in 5 to 8 days in October. One female may lay 20 eggs. The larva feeds on the inner rolls leaving the outer sheath untouched. The larval period is 10-16 days during March, April, 4-7 days during May-October, and 20 to 30 days in November, December, or the larva overwinters and pupates in the following spring. If the roll dries up the larva is able to remain dormant for seven weeks and recover if moist conditions return, but if dried out completely it dies. The pupa is formed naked in a cavity within the roll; the pupal stage lasts 3 to 6 days during March-October and 5 to 9 days in November, December. There are eight generations in a year in north India. The first generation beetles emerge in March from rolls formed in October; beetles emerging in December do not survive the winter.

Apoderus sissu is most abundant in March, April and again during the monsoon being dependent on the production of young foliage. Old leaves are rarely rolled. Rapid multiplication in July and August results from the short life-cycle of 10 to 15 days and the long life of the beetle. For control see Part Two.

LITERATURE:

Beeson, 1938, *Ind. For. Rec*, Ent., IV, No. 1, pp. 16-18, Guide to the insects of Dalbergia sissoo.

Stebbing, 1914, *Ind. For. Ins.*, pp. 418-422, figs. 282, 266 (descriptions and illustrations of the insect and its work).

Gardner, 1934, *Ind. For. Rec.*, XX, ii, Immature Stages of Indian Coleoptera, (14), pp 6-7 figs. 6, 7 (description of larva)

Voss E., 1935, *Ind. For. Rec.*, Ent., 1, 5, p. 100, Neue Attelabiden (description of variety).

Apoderus tranquebaricus, leaf-roller of *Mangifera indica, Persea gratissima, Shorea robusta* and *Terminalia catappa.* The apical part of the leaf is cut across transversely and the midrib is severed; the almost detached portion of the leaf is rolled transversely to form a cylindrical packet attached laterally. See Ayyar T. V. R., 1922, *Agr. Res. Inst., Bull.* 125, p. 12, pl. viii, fig. 1 and pl. vii.

Arrhines languidus, a dark brown hairy weevil, without scales, about 6 mm. long, feeds on *Zizyphus jujuba.*

Astycus aurovittatus, an elongate weevil with narrow light green stripes on a black ground, length about 3/8ths of an inch, feeds occasionally on teak in south India nibbling small holes in the edges of the leaves. The larval life is passed in the soil.

Astycus chrysochlorus is a polyphagous species injurious to the young foliage of *Camellia theifera, Hevea braziliensis* and *Pithecolobium saman.*

Astycus immunis see **Brachyaspites tibialis.**

Astycus lateralis is green with a lighter coloured lateral band and feeds similarly on teak leaves in Burma and north India; it also defoliates *Aleurites fordii* and *A. montana* plantations in the Federated Shan States, and is reported as a pest of tea bushes, *Bombax malabaricum* plants in taungyas, *Erythrina indica,* and *Mo us* spp.

Atmetonychus peregrinus. The beetle feeds on foliage of *Prunus communis, P. persica* and *Zizyphus jujuba.*

Attelabus see **Henicolabus** and **Paramecolabus.**

Auletobius fuliginosus is a dull brown weevil more than a quarter of an inch with a long rostrum, which girdles the young shoots and leaders of small *Terminalia myriocarpa* by boring deep holes into the bark. The rostrum is thrust into the shoot up to the insertion of the antennae and then withdrawn and a new hole is made close alongside. The shoot dries up and drops off.

Auletobius longicollis girdles the young shoots of *Hopea parviflora* (as described for *fuliginosus* above). The larva bores in the severed portion of the shoot.

Auletobius nigrinus feeds on young shoots of saplings of *Quercus incana.*

Balaninus c-album breeds in the fruits of *Eugenia jambolana.* For figure of beetle, see *Agr. Res. Inst., Bull.* 125, 1922, pl. XI, fig. 1.

Balaninus gilvonotatus breeds in the fruits of *Ficus glomerata,* emerging in July, August; pupation takes place in the soil. The larva is described by Gardner, 1934, *Ind. For. Rec.*, XX, ii, p. 72, figs. 20–23.

Balaninus punctum breeds in the fruits of *Ficus glomerata* emerging in May.

Balaninus ravus breeds in the fruits of *Ficus glomeratus* emerging in May.

Balaninus roridus breeds in the fruits of *Ficus glomeratus* emerging in August.

Baris achyranthis bores green stems of *Achyranthes aspera*; the larva, 8 mm. long, is described in *Ind. For. Rec.*, Ent., III, No. 12, p. 238.

Baris cordiae breeds in the fruits of *Cordia myxa* emerging in June.

Baris portulacae, a borer of the green stem of *Portulaca grandiflora* and *P. oleracea*; the larva is described by Gardner, 1934, *Ind. For. Rec.*, XX, ii, p. 26, figs. 37, 38.

Brachyaspites tibialis feeds as beetle on the foliage of *Acacia* sp., *Camellia theifera* and *Erythrina lithosperma*.

LITERATURE :
1928, *Journ. Tea Res. Inst., Ceylon*, I, 2, pp. 45, 46, 88.
1932, *Trop. Agr.*, LXXVIII, 3, p. 138. (as Astycus immunis bilineatus).

Brachytemnus see **Stenoscelis.**

Brachyxystus subsignatus, the beetle is a defoliator of *Abies webbiana*, *Cedrus deodara* and *Picea morinda*.

Calandra glandium. This weevil [fig. 4, No. 19] is a pest of the acorns of *Quercus dilatata*, *Q. incana*, *Q. glauca*, *Q. lanuginosa*. The egg is laid on the young acorn above the cupule; the early mines of the young larva run throughout the acorn but later work is concentrated at the basal portion often leaving the tip entirely untouched. Pupation takes place in an elongated cell formed on the outer part of the acorn near its base. The walls of the cell are smooth and lined with particles of silky hairs derived from the outer skin of the acorn. Throughout its life the larva is a fat obconical grub but becomes cylindrical just before pupating. Many individuals (up to 10) reach maturity in one acorn and the pupal cells are crowded closely and orientated at all angles. Emergence in March-July occurs by means of a circular hole, before which the acorn shows no signs externally of being attacked. There are at least two generations a year one of which overwinters in fallen acorns. This species is occasionally responsible for the destruction of nearly the whole crop of acorns. This species is recorded as *Calandra sculpturata* Gyll. by Stebbing, 1914, *Ind. For. Ins.*, pp. 446-448.

Calandra linearis bores the seeds of *Tamarindus indica*.

Calandra oryzae is an important pest of stored grains, particularly rice and wheat; it has a minimum life-cycle of 20 days. The beetles wander into various places in search of shelter and therefore are frequently found under the bark of logs and in stacks of stored timber.

Calandra rugicollis, a small black rugose weevil [fig. 4, No. 21], is a borer of the seeds of *Dipterocarpus alatus*, *D. tuberculatus*, *D. turbinatus*, *Eugenia jambolana*, *Melanorrhoea usitata*, *Polyalthia longifolia* and *Shorea robusta*; emergence is prolonged and occurs throughout the monsoon and cold weather

from July to March and is greatest in August-October. The larva, 4 mm. long x 2.3 mm. wide, is described by Gardner, 1934, *Ind. For. Rec.*, XX, ii, pp. 39, 40, fig. 99.

Calandra stigmaticollis, a borer of the trunk of *Cocos nucifera*. [Fig. 82 shows the larva, pupa and beetle].

Calandra vateriae, 3·5 mm., breeds in the seeds of *Vateria indica*.

Calandrotropus punctiger in wood of *Terminalia tomentosa*.

Camptorrhinus affinis, dark brown, the apices of the elytra and sides and legs in lighter colour, is a wood-borer of *Dipterocarpus turbinatus*, *Garuga pinnata*, and *Lannea grandis* with two generations per annum, emerging in February to April and June, July.

Camptorrhinus albizziae is a borer of *Albizzia lucida* and *Shorea robusta*; there are apparently two generations with emergence in April and October. The larva, 8 mm., is described in 1934, *tit. cit.*, p. 20, fig. 45.

Camptorrhinus dorsalis bores the wood of *Lannea grandis* and other trees in Ceylon.

Camptorrhinus mangiferae, borer of *Mangifera indica*; the beetle emerges at the beginning of the monsoon, (end June-end August).

Camptorrhinus scrobicollis, brown with white and black and light coloured speckling, is a borer of *Erythrina suberosa*, *Hardwickia binata*, *Lannea grandis*, *Shorea robusta* and *Vateria indica* with at least two generations per annum emerging in April, May from overwintered larvae and possibly as late as June, and again postmonsoon in October, November. The larva, 8 mm., is described in 1934, *tit. cit.*, p. 26, fig. 46.

Cercidocerus lateralis, a borer of *Gmelina arborea* emerging in July.

Chelothippia buteae bores as larva in living twigs and small branches of *Butea frondosa*; the larva, 12 mm. long, is described by Gardner, 1938, *Ind. For. Rec.*, Ent., III, No. 12, p. 241, figs. 30, 31. [fig. 84].

Cionus albopunctatus. The beetle feeds on the foliage of *Dolichandrone stipulata*.

Cionus transsquamosus, a globular weevil with bright yellow spots on a brownish-yellow ground, defoliates *Buddleia asiatica*. The larva is an external feeder on the leaf; it is covered with a shiny substance and pupates in an almost spherical brown horny cocoon.

Cleonus piger. The beetle eats the leaves of *Salix alba*.

Conarthrus jansoni and **C. vicinus** live in *Dendrocalamus strictus* attacked by Bostrychidae.

Coniatus indicus is a defoliator of *Tamarix gallica*. The life-history is given in *Agr. Res. Inst., Pusa, Bull.* 89, pp. 20, 21 figs. 11 (1919).

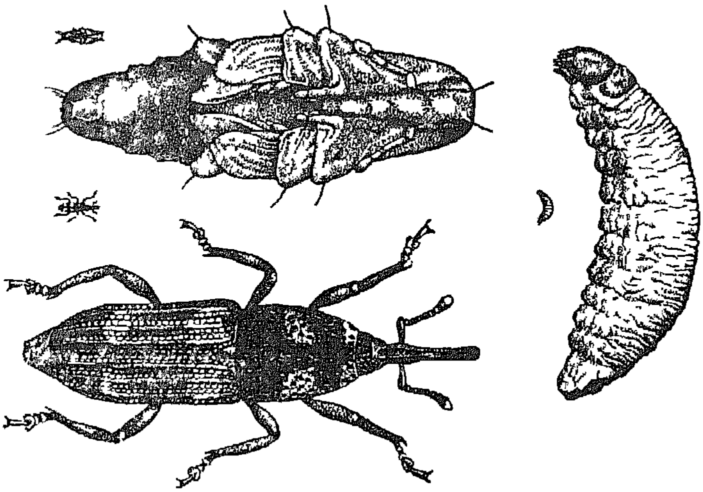

Fig. 82. Calandra stigmaticollis, larva, pupa and beetle; the small figures are natural size.

Cosmopolites sordidus is a pest of cultivated plantains boring the lower part of the stem. There is an abundance of literature, see *Trop. Agr.*, 1921, p. 374.

Cossonus albizziae is a borer of the wood of *Albizzia* spp.

Cossonus bimaculatus bores the wood of *Anogeissus acuminata*.

Cossonus binodosus is widely distributed in north India as a secondary borer of *Alnus nitida*, *Euphorbia royleana*, *Ficus glomerata*, *Juglans regia*, *Mallotus roxburghianus*, *Ricinus communis*, and *Terminalia belerica*. The life cycle takes one year to three years and emergence occurs from June to October, mainly in July. The larva, 8 mm., is described by Gardner, 1934, *Ind. For. Rec.*, XX, ii, p. 34, figs. 106–110.

Cossonus canarensis bores the wood of *Ficus bengalensis*.

Cossonus disciferus bores the wood of *Artocarpus integrifolia*. The emergence period is prolonged and may continue for 12 months into the second year. The majority emerges in May and in August, September.

Cossonus ficus bores the wood of *Ficus* sp.

Cossonus transvaalensis bores the wood of *Sterculia villosa*; emergence in July to September.

Cryptorrhynchus atkinsoni. The larva bores the bark and sapwood of *Acacia pruinescens*.

Cryptorrhynchus corni bores the bark and sapwood of *Cornus capitata*, emerging in June

Cryptorrhynchus frigidus bores the seed and the pulp of the

unripe fruit of *Mangifera indica* in Bengal to Burma. The life-cycle is completed in about 3 weeks. The larva is described by Gardner, 1934, *Ind. For. Rec.* XX, ii, p. 7, figs. 50, 51, (as *gravis* F.); see also *Proc. 3rd. Ent. Meet., Pusa*, 1919, pp. 204, 205, (as *gravis* Fb.)

Cryptorrhynchus inglorius bores the seeds of *Melanorrhoea usitata*.

Cryptorrhynchus mangiferae bores the seed in the fruit of *Mangifera indica*. See also *Trop. Agr.*, XLII, pp. 410, 411, (1914); *tit. cit.*, LXXXVI, p. 202 (1936); *Ceylon Dept. Agr., Bull.* 67 (1923).

Cryptorrhynchus quercus bores the acorns of *Quercus spicata*.

Cryptorrhynchus raja bores bark and sapwood of *Pinus excelsa*.

Cryptorrhynchus rufescens.

Is a borer of the bark and sapwood of *Pinus longifolia* and *P. khasya*. Its range is from Kashmir through Burma to Japan. (It was previously known in departmental literature as *brandisi* Stebb.)

Life-cycle: The eggs are laid in deep crevices or cracks in the bark of the tree or in pits gnawed for the purpose; the larva is a bark-borer making very irregular tunnels without definite direction but running for nearly 10 inches; these are circular in cross-section and packed with red dust. For pupation a shallow chamber is excavated, which may be mainly in the sapwood or wholly in thick inner bark; it is $\frac{1}{2}$–$\frac{3}{4}$ inch long, oval, and lined with coarse interlaced wood-fibres. On maturing in the cocoon of wood-fibres the beetle gnaws a straight exit-tunnel to the outside. There are possibly 3 generations a year. The beetles of the overwintering generation emerge from April onwards. Eggs laid in April give rise to beetles at the end of June; a second generation may be completed between July and September and the third overwinters in any stage, larva, pupa, or beetle.

Economic importance: The beetle (fig. 4, No. 21), attacks living chir saplings, poles and trees that are sickly, burnt, injured by fire or other accidents, diseased owing to fungus attack. This species was for many years considered to be a primary pest of young living pine especially in chir plantations; the larva bores in living bark causing the outpouring of quantities of resin and the formation of cankerous wounds; the tree dies. In such cases *C. rufescens* is closely associated with the attacks of the pine blister-rust, *Peridermium himalayense*, and is definitely secondary to the disease. The weevil larvae bore in the diseased tissues and in the relatively healthy tissues nearby in the bark and cambial region, and thereby hasten the girdling of the stem which causes the tree to die.

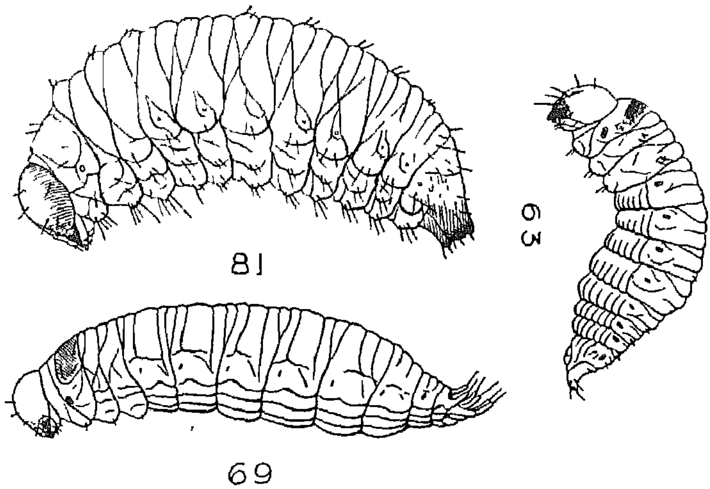

Fig. 83. Larvae of Curculionidae

No. 81. *Amblyrrhinus poricollis*, natural size 6 mm., lives in the soil.

No. 69. *Anisus pauperatus*, natural size 5 mm., bores in wood.

No. 63. *Trochorrhopalus balwanti*, natural size 8 mm., bores in a climber.

Mature trees and seed bearers dying through exposure or from fire injuries are attacked by *rufescens* over the whole of the shady side of the trunk including the thickest bark near the roots.

LITERATURE :
Bagchee K. D., 1929, *Ind. For. Rec.*, Bot., XIV, iii, pp. 79-101, Investigations on the infestations of Peridermium complanatum and P. himalayense.
Champion H. G., 1922, *Ind. Forester*, XLVIII, pp. 168-174, pl. 4, figs. 1, 2, On the death of chir poles in the Almora plantations of Kumaon.
Gardner J. C. M., 1934, *Ind. For. Rec.*, XX, ii, pl. 16, fig. 52 (as *brandisi*), Immature stages of Indian Coleoptera (14) Curculionidae.
Stebbing E. P., 1914, *Ind. For. Ins.*, pp. 428-436, pl. XXXVI, XXXVIII, (Cryptorrhynchus brandisi).

Cryptorrhynchus spondias is a borer of the bark and sapwood of *Spondias mangiferae*; the beetles emerge in April, May.

Ctenomerus lagerstroemiae bores the fruits of *Lagerstroemia flos-reginae*.

Curculio see **Balaninus.**

Cyphicerinus tectonae defoliates *Tectona grandis* in India early in the season; the youngest partly expanded leaves are not attacked but the older though still tender leaves are closely perforated by the beetles.

Cyphicerus humeralis defoliates *Tectona grandis* in south India, and **C. interuptus** does so in Burma.

Cyrtepistomus glebosus and **C. pini**; the beetles, 5-7 mm., eat the needles of *Pinus longifolia.*

Cyrtepistomus jucundus. The larva of this otiorrhynchine, which occurs in the soil of deodar nurseries, is described by Gardner, 1934, *Ind. For. Rec.* XX, ii, pp. 9, 10, figs. 12-14.

Cyrtepistomus pannosus feeds on *Tectona grandis* nibbling the edge of the leaf in April-July.

Cyrtotrachelus birmanicus, a black or reddish polished weevil with very long anterior legs fringed on the inner edge with long red hairs, length of body 1-1¼ inches. The larva bores the growing culms of *Melocanna bambusoides*; its habits are similar to those of *Cyrtotrachelus longipes.*

Cyrtotrachelus dux

A borer of young sprouting culms of bamboos, *Dendrocalamus hamiltonii, D. strictus* and probably other species; the new shoots are thereby destroyed or are prevented from growing. The beetle is reddish-brown above with some black marginal markings, and is black beneath; in the male the forelegs (femur and tibia) are longer and the fore tibiae are densely tufted with hairs; the size of the beetle varies between 20 to 40 mm. long and 8 to 15 mm. wide [see fig. 4, No. 25]. It is not certain that the species here treated as *dux* is distinct from the following species treated as *longipes* (*longimanus*); or whether only one species is represented in India; *dux* occurs in the submontane Himalayan region and Burma.

Life-history.

Habits of adult: The adult beetle feeds on the tender young culm shoots of bamboo at the beginning of the monsoon. A deep hole is bitten into the internode through its bare wall or through an ensheathing culm-sheath, and this hole may be enlarged to a slit or incision 1/2 to 1 inch long. When feeding the beetle usually has the head pointing downwards and the rostrum buried in the hole up to its base, and the body elevated behind. A beetle remains at one feeding-hole for several hours; in the insectary the same feeding-hole was used by one beetle for 14 days. When disturbed the beetles fly away or drop to the ground. The ingested food is almost wholly bamboo sap; some fibres are gnawed and shredded at the sides of the cavity. Holes that are tapped for a short time in very young shoots may fill up later with a white gummy exudation. Large and more permanent holes are visited by scavengers, e.g., coprid beetles (Scarabaeidae), Nitidulidae, dipterous maggots and also some other borers. The culm is thus prevented from continuing its growth, it remains dwarf, with short shrunken internodes, or begins to rot or dry up (according to the weather).

Pairing takes place on the new culms. The long forelegs of

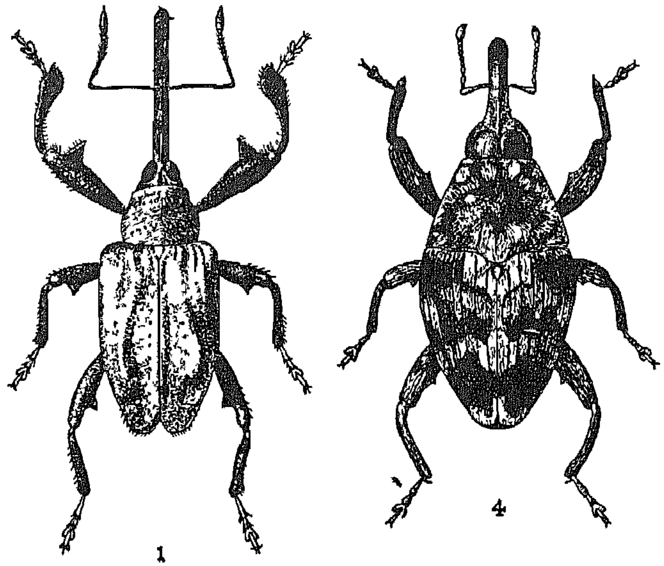

Fig. 84. No. 1. Drepanoscelus gardneri, female beetle, natural size 5 mm.
No. 4. Chelothippia buteae, female beetle, natural size, 3 mm.

the male grip along each side of the head and rostrum of the female during coupling.

O v i p o s i t i o n: For the reception of the egg, pits similar to feeding pits are bitten out 1/2 to 1 inch long and 1/8th to 1/3rd of an inch deep. The white elliptical egg is laid parallel to and under the thin epidermis of the internode and not perpendicular to its long axis and *without any special protection of gum or wood-dust.* Only one egg is laid in one pit. In one culm 3 or 4 eggs may be laid at various places. The culm selected for oviposition is usually less than 4 ft. high and the oviposition site is some inches (up to about 10 inches) below the apex, the culm, of course, grows rapidly after the egg has been deposited.

L a r v a l t u n n e l. Hatching takes place in 1 or 2 weeks. The larva bores in the thickness of the internodal wall travelling upwards from the egg-pit. The tunnel runs irregularly from side to side sometimes grazing the internal surface of the wall and sometimes reaching the external rind, thus making ejection holes. The nodes are perforated as the larva passes successively through them towards the apex of the shoot which is soft and solid. This upper portion of the culm is eaten out and refilled with excreta so that it becomes a pulpy mass. In this more nutritious region the

larva increases rapidly in size and the further growth of the culm is arrested. In the earlier stages of the larval life of the borer there is a race between the larva and the bamboo; it is essential for the larva to tunnel more quickly than the bamboo elongates, in order to overtake the growing tip. This preliminary tunnel in the woody part of the bamboo consequently varies in length in culms of different history, and may be anything from one to 15 ft. long. The larva of the early instars does not bore downwards or return on its tracks.

The dead and hollowed upper part of the culm is limited at a node by a fairly sharply cut surface from the more lignified lower part and it readily breaks away or falls off. Monkeys, woodpeckers and deer may break it off; or filled with bamboo dust, heavy and sodden with rain it falls under its own weight.

Pupation: The full grown larva, which is then 4 to 6 weeks old escapes from the fallen top and travels over the ground in search of a good place to burrow in for pupation. It buries itself in loose moist soil to a depth of several inches and forms a large cell of earth and vegetable debris which is thick walled and smoothly lined internally.

The pupal period is relatively short, 3 or 4 weeks, the transformation to beetle taking place at the close of the monsoon season in September. For the rest of the year, winter and dry hot weather, the immature beetle remains in its earthen cell, until the recurrence of the monsoon soaks the soil and softens the cell wall and stimulates the beetle to emerge. The life-cycle is thus annual with a resting imaginal stage of ten months.

Like the larva of the palm weevil, *Rhynchophorus ferrugineus*, that of the bamboo weevil is eaten by aborigines; they cut off the top of the culm in order to extract the larva; e.g., in Bastar State.

Economic importance.

Damage by *Cyrtotrachelus* is characterised by a long tunnel starting at a shallow excavation beneath or near a culm-sheath and passing internally through several internodes, grooving the inner side of the wall, perforating each node passed and terminating in a hollowed out and killed terminal shoot. The dead top of the culm may surmount a length of anything from a foot to 15 feet and this portion is not killed; also the culm may die right back at the beginning of the monsoon before it has made any lignified tissue.

In the top-killed culms the energy of growth is diverted to new leaders which arise from the upper nodes; as many as 14 new switches competing for leadership may be produced from one culm. This secondary growth is of no commercial value; on the contrary it causes congestion by interlacing.

A single larval borer of this species is sufficient to spoil a culm; and one beetle may spoil many culms: (a) if the attack

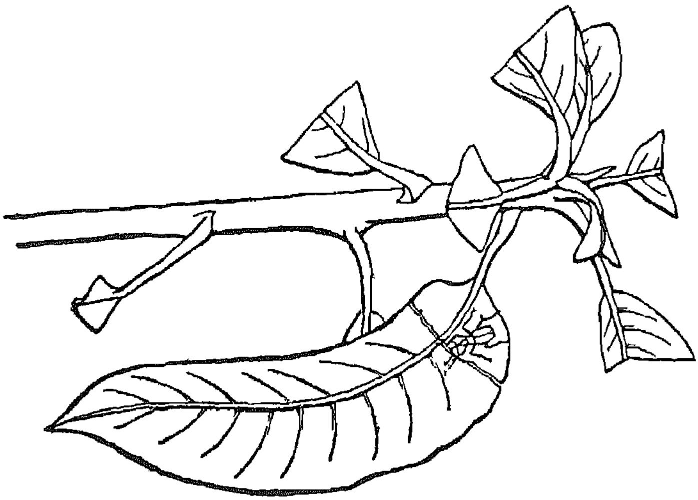

Fig. 85. Leaves of Mangifera indica cut by beetles of Deporaus marginatus (slightly reduced).

occurs early no culm at all is formed, (b) if attacked later in the season a stump or short culm with switches is formed, (c) if the attack fails a useful length of bamboo is available although water entering through the perforated nodes discolours the inside of the portion that lives on.

The borer-damage is more abundant where the bamboo clumps are dense and numerous. No appreciable difference occurs in the incidence of attack under shade conditions varying from light high to heavy low shade. For control measures see Part Two.

LITERATURE :

1937, *Ind. For. Rec*, Silv, II, No. 4, pp. 85, 163, 170, 171 (as *Cyrtotrachelus longipes*).

Marshall G. A. K., 1916, *Faun. Brit. Ind.*, Coleoptera, Curculionidae, fig. 6 (beetle).

Cyrtotrachelus longipes.

A borer of young sprouting culms of *Dendrocalamus strictus*, *Melocanna bambusoides* and other species of bamboo. The beetle very closely resembles *C. dux* [see fig. 4, No. 25] and as mentioned under *dux* it is uncertain if the account which is here referred to *longipes* represents a separate species or not; there are differences in the life-history.

Life-history.

The main points in which the life-history differs from that recorded for *dux* are as follows, but it is not impossible that all are variations in the habits of one and the same species.

CHITTAGONG HILL TRACTS: According to Stebbing, 1914, *Ind. For. Ins.*, pp. 440–443, the beetles appear at the end of May with the arrival of the monsoon and remain until the middle of August. The larva on hatching bores to the centre of the culm and "then invariably bores downwards, eating away the soft central portion and increasing in size at a rapid rate. It continues feeding downwards until it reaches the base of the shoot, by which time it is full-fed. The grub then retreats back up its gallery, probably enlarging the upper portions, which will be now too small for it, reaches about the place it started from. It then cuts this portion off, gnawing it through all round below it. The top drops to the ground and the now fully mature larva burrows into the soft rain-loosened earth, carrying the top or a portion of it with it, thus completely sheltering itself from atmospheric influences .... The larva changes to the pupal state within the fallen buried end of the shoot at a depth of three to four inches .... The top of the shoot soon rots, only the harder fibres persisting. Inside this fibrous covering ... the pupa remains during the following cold and hot seasons, emerging as a beetle at the commencement of the ensuing rains .... Some ten months of the insect's life-history are passed in the pupal stage, about five weeks in the imago and egglaying stage ... and three to four weeks in the larval or destructive stage."

CENTRAL PROVINCES: According to Witt, 1913, *Ind. For.*, XXXIX, pp. 265–272, the beetles appear towards the end of July coincidently with the sprouting of new bamboo shoots. Oviposition may continue through September. Eggs hatch in 3 to 5 days. The larva on hatching usually bores upwards and not downwards and never by any chance reaches the base of the shoot. It does not cut off the terminal portion of the shoot but "works its way to the surface of the shoot and emerges through a large round hole which is clearly visible, and thence falls to the ground". The length of the larval feeding stage is about 3 weeks, and pupation occurs about 2 weeks later. The larva burrows into the soil for 9 or 10 inches to make its pupal cell "... the normal form of cell in which the larva pupates is an earthen cell and contains no trace of bamboo fibres in its composition .... In this cell the pupa remains until the following July or August when it emerges as a perfect insect". Witt thus puts the pupal period at 9½ months.

CHINA: Chen, 1928, pp. 353–366, figs., gives the life-history of the bamboo borer near Canton under the name of *longimanus*. The beetle is 21–33 mm. long by 8.3–15 mm. wide; the egg is 3.7 mm. long × 1.4 mm. wide. There are 5 larval instars and the mature larva is 32 mm. long × 14 mm. wide. The egg hatches in 2 or 3 days. The larva on hatching in the egg-pit "begins to work its way upward or downwards (more often the latter) to the

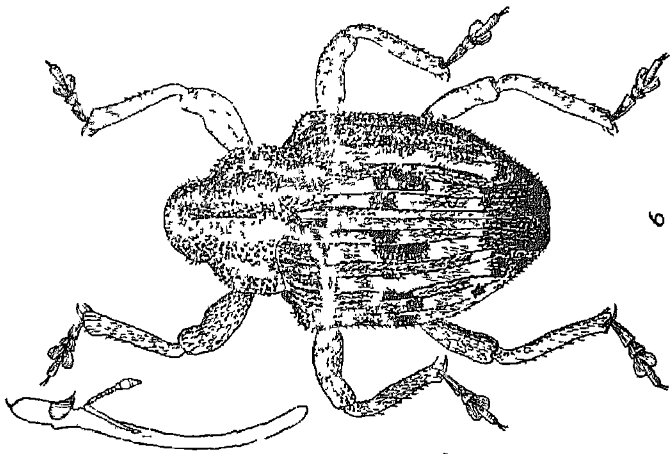

Fig. 86. Dinobaris longirostris, female beetle natural size 7 mm.

tender part where it feeds and consequently makes a burrow. Sometimes the larva is seen to burrow downwards at the beginning but later to change the direction and burrow upward... While the larvae are burrowing and feeding forward, they leave behind a mass of sawdust-like material". The full grown larva is almost as large in diameter as the bamboo shoot which becomes a hollow cylinder packed with wooddust. The larval stage lasts 14 to 17 days. "The grub in the latter part of the 5th instar stops feeding and leaves the bamboo shoot. The larva having reached full size burrows to the outside of the shoot, near a node. This weakens the upper part of the shoot, which is practically filled with the sawdust like material, and causes it to fall to the ground.... It then wriggles from the old home, or falls from the shoot as the latter strikes the ground It then bites off a piece of the bamboo tissue and carries it to the place where it commences to make its burrow. Whether or not the piece of bamboo is actually carried down into the soil is not known". Pupation occurs in a hard strong cell, the pupal period lasts for about 12 days and the total number of days elapsing from egg to adult is from 40 to 44.

Larval locomotion: Hoffman in the same article describes the process of crawling when the mature larva, having left the fallen culm-top, wanders in search of a suitable site for pupation, sometimes dragging with it a piece of the culm 2 or 3 inches long A distance of one yard may be travelled in 15 minutes. Crawling is accomplished by undulations of the body and also by use of the mandibles, the larva crawls largely on its side, the median dorsal line of the body being always to one side or the other.

"At a point about one third of the distance from the posterior end the body is larger in circumference, two of the segments being much larger and serving much as prolegs in a lepidopterous larva. The undulations proceed from the rear to the front and as this takes place the several body rings are pushed down ventrally and come into contact with the ground. The caudal end is raised, slightly arched and placed forward after which a projection on the ventral side at the tip of the abdomen is placed down firmly. The undulations then travel forward like waves surging toward the seashore. When the region of the thorax is reached by these undulations, the mandibles are placed about a quarter of an inch forward and are used to pull the body . . . . . When crawling with the posterior end of the body inside the small bit of culm the larva resembles a large bagworm. Locomotion must be much more difficult in such a case, not only because of the burden of the load but also because the larva is deprived of the use of the caudal end of the body. When disturbed the larva quickly retreats within the piece of culm." This piece serves to protect the larva from excessive drying and possibly from certain animal enemies; in case the soil at first is too hard for burrowing the larva has protection and also food during a further period of search for moist or soft soil.

Pupation: Having found a suitable place the larva burrows into the earth and may reach a depth of 10–12 inches. The piece of bamboo or parts of it are dragged into the burrow and the fibres mixed with soil are used to construct a cocoon or cell for pupation. The inside of the cell is hard and smooth and the walls are thick and form a good insulation to heat and desiccation. The prepupal and pupal periods together take 3 or 4 weeks. The immature beetle does not leave the cell but passes the autumn, winter and hot weather in a resting condition until the onset of the monsoon rains soaks the soil and softens the pupal cell. The life-cycle is thus annual with an egg stage of 2 or 3 days, larval period 14–17 days, a prepupal period of 12 days and pupal period of about 12 days. The adult passes the winter and summer in the cell inactive and without food. The habits of the beetle are the same as those of *C. dux*.

For control measures see Part Two.

LITERATURE:

Chen H. T., 1928, *Lingnan Sci. Journ.*, VI, pp. 353-366, figs. Notes on a bamboo borer Cyrtotrachelus longimanus.

Gardner, 1934, *Ind. For. Rec.*, XX, II, p. 38, 39, figs. 97, 98 (larva of C. longipes.

Stebbing, 1914, *Ind. For. Ins.*, pp. 440-443, pl. xxxviii, C. longipes.

Witt D. O., 1913, *Ind. For.*, XXXIX, pp. 265-272, pl. 5, Notes on the life-history of Cyrtotrachelus longipes.

Cyrtozemia cognata, a black shining weevil with convex elytra and swollen body, length about 6 mm., decorticates the shoots of *Acacia arabica* in Central India.

Demimaea luctuosa. The larva, 8 mm., bores the living shoots of *Ficus hispida*, beetles emerging in August, September. Larval characters are given in *Ind. For. Rec.*, Ent., XX, ii, pp. 30, 31, figs. 90 93.

Deporaus marginatus, reddish-brown with the tips of the elytra and rostrum dark, is a defoliator of *Butea frondosa* and *Mangifera indica*. The weevils feed by eating away small patches of epidermis, the injured areas turning brown and the leaf curling up or crumpling. Pits are dug by means of the rostrum in the thick midrib of the leaf and eggs are deposited in the pits. The leaf is then cut right through near the base or through the petiole and falls from the tree. [fig. 85]. The larvae feed as miners in the leaf-tissue and when mature emerge and pupate in cells in the soil. The total life-cycle averages 25 days and adults live for 3 months.

LITERATURE :

Fletcher T. B., 1914, *Some South Indian Insects*, p. 330.
Ayyar T. V. R., 1922, *Agr. Res. Inst. Pusa*, Bull. 125, p. 14, pl. x, figs. 2, 3.
Hutson, J. C. and Alwis, E. De, 1934, *Trop. Agric.*, LXXXIII, pp. 128-132, coloured plate, 7 figs. (Eugnamptus marginatus).

Dereodus mastos, the beetle defoliates *Acacia arabica*.

Dereodus pollinosus, an elongate black weevil dusted with yellowish or pinkish scales, length about 10 mm., feeds on the foliage of *Calotropis*, *Euphorbia prolifera*, *Pyrus malus*, *Quercus incana* (seedlings), *Robinia pseudacacia*, *Shorea robusta*, and *Zizyphus jujuba* in northwest India.

Dereodus sparsus, the beetle feeds on the leaves of *Zizyphus jujuba*.

Desmidophorus hebes. The beetle feeds on the young shoots and stems of various Malvaceae, scraping the epidermis, biting holes or chewing completely through the softer shoots particularly of young plants. The species attacked are *Acacia monoflora*, *Bombax malabaricum*, *Hibiscus* spp., *Kydia calycina*, *Mangifera indica and Urena lobata*. It sometimes appears in very large swarms.

Dicranognathus nebulosus breeds in the acorns of *Quercus incana* emerging in July, August. The larva, 9 mm. long, is described by Gardner, 1934, *Ind. For. Rec.*, XX, ii, pp. 7, 8, figs. 1–5.

Dinobaris longirostris bores the seeds of *Polyalthia simiarum* emerging in September. [fig. 86, beetle, 7 mm.].

Diplophyes shoreae breeds in the seeds of *Shorea robusta* in Assam ; the beetles emerge in June.

Drepanoscelus gardneri, [5 mm., fig. 84, No. 1], feeds as larva in the small fleshy fruits of *Machilus duthiei*, pupating therein and emerging as beetle in July. The larva, length 10 mm., has an unusual modification of the hind end of the body ; it is described by Gardner, 1938, *Ind. For. Rec.*, Ent., III, No. 12, pp. 231, 232, figs. 1–6.

Dryophthoroides parvungulis bores the wood of *Evodia fraxinifolia*, *Juglans regia*, and *Machilus*. The larva, 5 mm. long, is described in *Ind. For. Rec.*, Ent., III, No. 12, p. 253, figs. 72, 73.

Dystropicus clitellae is a borer of the wood of *Bombax malabaricum* emerging in April, May.

Dystropicus dorsalis is also a borer of *Bombax malabaricum*, emerging in April, May. The larva, 10 mm. long, is described by Gardner, 1934, *Ind. For. Rec.*, XX, ii, p. 17, figs. 47-49.

Emperorrhinus defoliator, a small weevil, black with green speckling, antennae rather long and slender, length 3 mm., sometimes appears in July in the Himalayas in swarms which travel slowly over the hillside feeding on most soft-leaved trees and shrubs in their path but particularly defoliating wild pear, artificial fruit orchards (pear, apple, peach) and *Alnus nitida*. The defoliation within the affected area is very severe but the territory invaded is relatively limited.

Episomus lacerta, the beetle has the abdomen much swollen and elytra convex, dirty brown above and lighter coloured below, length 10 mm., and feeds on *Acacia cyanophylla*, *Dalbergia paniculata*, *Erythrina indica* and *Tectona grandis* and also cultivated beans in south India. Eggs are laid in a batch on the leaf which is folded over as a protection and gummed in position by a sticky secretion. The larvae on hatching gnaw through the leaf and drop to the ground and entering the soil feed on the rootlets of plants. The female is long-lived and may lay over one thousand eggs.

Eremotes see **Xenomimetes**.

Eugnathus alternans, the beetle feeds on the foliage of *Mucuna pruriens*.

Eugnathus curvus, the beetle feeds on the foliage of *Butea frondosa*.

Euops gardneri, an attelabine, defoliates *Machilus odoratissima* in September.

Exodema ilicis, a cossonine, is a borer of the wood of *Ilex* sp.

Gasterocercus anatinus is a borer of the wood of *Celtis australis*.

Gymnetron amictum, the larva feeds inside the fruit of *Verbascum thapsus*.

Gymnetron anagallis, the larva, 5 mm. long, bores inside the living stem of *Veronica anagallis* forming a gall-like swelling. • It is described in *Ind. For. Rec.*, Ent., XX, ii, pp. 31, 32, figs. 32-36.

Henicolabus discolor the beetle rolls the leaves of *Terminatia* spp.

Henicolabus octomaculatus, a yellow beetle with 8 black spots on the elytra rolls the leaves of *Grewia hirsuta* and *G. tiliaefolia*.

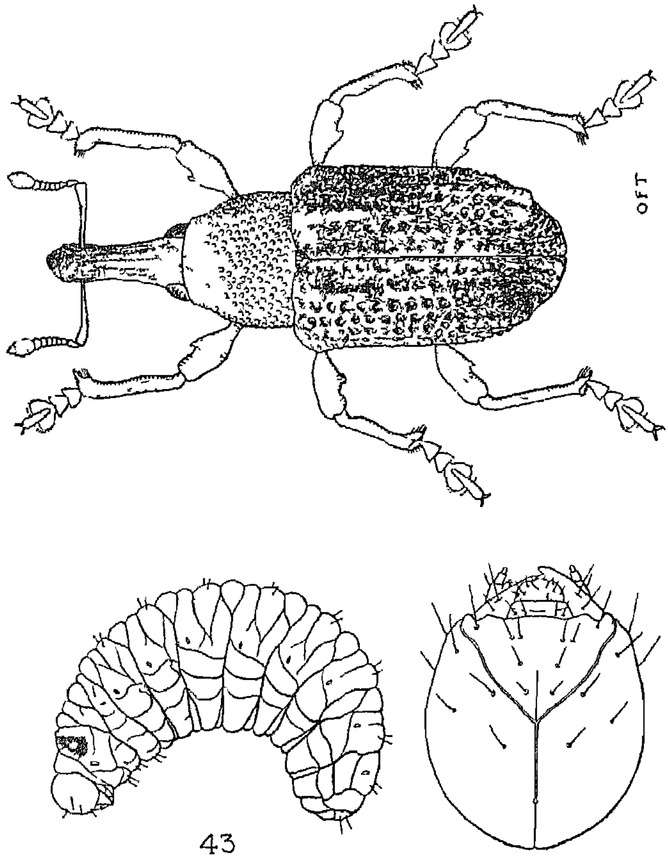

Fig 87 Kozubo crassus, male beetle, natural size 12 mm.; larva (No 43) natural size 18 mm ; head of larva, dorsal view.

Ayyar T V R, 1922, *Agr. Res Inst*, Bull 125, p 13, pl ix, fig. 4 (as Attelabus octomaculatus)

Himatinum asperum, a cossonine, bores the sapwood of *Shorea robusta*.

Himatinum lineare bores the sapwood of *Calophyllum walkeri*.

Hylobius angustus, reddish brown weevil with transverse white markings, ½ an inch long, which attacks the leaders and lateral shoots up to about one inch in girth of *Pinus excelsa* and *Cedrus deodara*, gnawing off the bark in a series of pockets until the wood is exposed. When the attack extends all round the shoot it is girdled and dies. Eggs are laid on small sickly saplings

of *Pinus excelsa* and occasionally of *Picea morinda*, particularly those damaged by snow slides, rocks, fellings, etc. The larvae bore under the bark of the bottom six inches of the stem, and underground in the main roots; the tunnels are filled with coarse frass and a copious flow of resin occurs. Some 15 larvae may develop in one sapling which is eventually girdled and dies in the early hot weather. The larva, 15 mm. long, is described by Gardner, 1938, *Ind. For. Rec.*, Ent., III, No. 12, p. 235, figs. 48–50. Pupation occurs at or below ground-level in oval concavities on the surface of the wood in cocoons of fibres. The beetles emerge in May–July. For control measures see Part Two.

Hypera variabilis, the beetle feeds on the foliage of *Pyrus communis* and *P. malus*.

Hypomeces squamosus, the beetle feeds on the foliage of *Aleurites montana*, *Bombax malabaricum*, *Cassia fistula*, *Hevea brasiliensis*, *Hibiscus rosa-sinensis* and sometimes of *Tectona grandis*.

Kobuzo crassus, Hylobiinae, bores the fruit of *Quercus spicata*. The larva passes the cold season in the fruits and the beetle emerges in March. The larva, length 18 mm., is described by Gardner, 1938, *tit. cit.*, pp. 235, 236, figs. 43–47. [fig. 87].

Larinus onopordi and **L. syriacus** and other species in Asia Minor, Persia and Northern India have larvae which leave the flower-heads when full-grown and construct on the stem of the plant a nódular cocoon, of the size of an olive, formed of a dirty, white, chalky substance secreted by the Malpighian tubes. These cocoons form an article of commerce in the East, being largely used both medicinally and as a food. The constituent materials have been found to contain about 66 percent of a sago-like substance, known as trehalum, and 28 percent of a sugar allied to cane-sugar and called trehalose. For medical purposes a decoction is made from the cocoons before the weevils have matured, and this is considered to a be a very effective remedy for bronchial catarrh. (Marshall, 1916).

Larinus saussureae, a dark brown weevil with grey markings, 6–10 mm. long, attacks the flower heads of the thistle, *Saussurea candicans*, destroying the seeds and checking the spread of this weed. Eggs are laid in a puncture in the unopened flower head at the end of March to mid-April. The larva, 16 mm. when fullgrown, feeds on the receptacles and developing fruitlets. A thin cocoon of vegetable shreds gummed together with an anal secretion, applied with the mandibles is formed in the flower head. Sometimes 2 or 3 larvae inhabit one thistle flower. The larva is described by Gardner, 1934, *Ind. For. Rec.*, Ent., XX, ii, p. 23, figs. 16–19. Pupation occurs in the cocoon.

Lixus aethiops. The larva is a borer of the living stem of *Blumea lacera;* it is described in 1939, *Ind. For. Rec.*, Ent., III, No. 12, pp. 237, 238, figs. 35, 36.

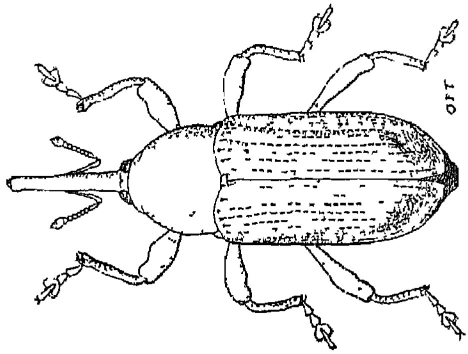

Fig. 88. Mecobaris terminaliae, natural size 7 mm.

Lixus auriculatus. The larva, 15 mm. long, is a borer of the living stem of *Amarantus* spp. and *Chenopodium album*. It is described by Gardner, 1934, *Ind. For. Rec*, Ent., XX, ii, p. 23, 24.

Lixus truncatulus, a cleonine, is a borer of the branch and stem of *Amarantus caudatus*, *A. gangeticus*, *A. spinosus* and *A. viridis*, causing galls and swellings.

Ahmad T, 1939, *Ind Jl. Agr. Sci.*, IX, iv, pp 617-626
Gardner, 1934, *Ind For Rec*, Ent, XX, ii, p, 23, fig 15 (larva).

Lobotrachelus amoenus bores stems of *Urena lobata* emerging in April. The characters of the larvae of *Lobotrachelus* (Isorrhynchinae) occurring in *Urena lobata* are given in 1934, *tit. cit.*, pp. 29, 30, fig 72.

Lobotrachelus laporteae bores *Laportea terminalis* emerging in April, May.

Lobotrachelus subfasciatus bores stems of *Urena lobata* emerging in April–July.

Lobotrachelus urenae bores stems of *Urena lobata* emerging in July–August.

Macrorrhyncolus ventilaginis, a cossonine, is a borer of *Ventilago calyculata*.

Magdalis himalayana, borer of shoots and twigs of *Pinus longifolia*; the generation is annual and the beetle emerges in the spring (March).

Mecistocerus bardus, a mottled brown, black and pink, cryptorhynchine weevil, $\frac{1}{2}$ an inch long, a borer of *Bombax malabaricum*, *Ficus cunia*, *Mallotus philippinensis*, *Sterculia villosa*, with emergence in June

Mecistocerus corticeus is a borer of *Bombax malabaricum*, emerging in May, June. The larva, 18 mm. × 4.5 mm., is described in 1934, *tit. cit.*, p. 19, figs. 82–89.

Mecistocerus fluctiger is a borer of *Acacia catechu*, *Albizzia procera*, *A stipulata*, *Amoora wallichii*, *Anthocephalus cadamba*,

Bauhinia acuminata, Bombax malabaricum, Buchanania latifolia, Butea frondosa, Careya arborea, Cratoxylon nerifolium, Dalbergia sissoo, Erythrina indica, E. suberosa, Eugenia jambolana, Ficus bengalensis, F. religiosa, Garuga pinnata, Grewia vestita, Kydia calycina, Lannea grandis, Litsea polyantha, Mallotus philippinensis, Mangifera indica, Millettia atropurpurea, Morus laevigata, Olea glandulifera, Ougenia dalbergioides, Ostodes paniculata, Pterocarpus marsupium, Pterospermum acerifolium, Semecarpus anacardium, Shorea robusta, Spondias mangifera, Tectona grandis, Terminalia belerica, Thespesia populnea, Wrightia tinctoria, W. tomentosa, Zanthoxylum budrunga. Found throughout India and Burma.

The life-cycle is annual with emergence in April–July, but predominantly in May. The larva resembles that of *M. corticeus* but is on the whole smaller and there is overlapping in the size of the beetles.

Mecistocerus fossatifrons bores the wood of *Anthocephalus cadamba*, and *Turpinia* sp.

Mecistocerus fumosus, a black species with pink underside, bores *Pinus longifolia.* The larval tunnel runs horizontally from the sapwood surface inwards for about an inch and then turns vertically to form a short pupal chamber; the beetle emerges in July, August. In dry wood larval development may continue fcr more than one year.

Mecistocerus indignus bores the wood of species of *Premna* and *Vitex.*

Mecistocerus mollis bores the wood of *Bombax malabaricum* and *Erythrina indica*, emerging in June, July.

Mecistocerus raucus bores the sapwood of *Dalbergia cultrata.*

Mecistocerus ricini is a borer of woody stems of *Ricinus communis* emerging in May. The larva, length 12 mm., is described in 1934, *tit. cit.*, p. 19.

Mecobaris terminaliae bores the seeds of *Terminalia belerica* maturing in March–June. [fig. 88].

Mecocorynus varipes, a cryptorrhynchine, bores wood of *Anogeissus acuminata* and *Spondias mangifera.*

Mecopus bispinosus is a borer of *Artocarpus chaplasha, Canarium euphyllum, Ficus glomerata* and *F. minahassae.*

Mecopus hopei, a short-bodied weevil with slender legs, is a borer of *Ficus glomerata* and *F. rumphii;* emergence in April–June.

Mecysmoderes stylicornis. The larva, 8 mm. × 2.5 mm., lives in the buds of *Costos speciosa.* Several larvae may feed together in the succulent bud producing a more or less liquid mess. See 1934, *tit. cit.*, 10, 11, figs. 68–71 for description of larva (Ceuthorrhynchinae).

Metialma anisomelis. The larva *(tit. cit.*, p. 15, fig. 66), a zygopine, bores the living stem of *Anisomelis ovata.*

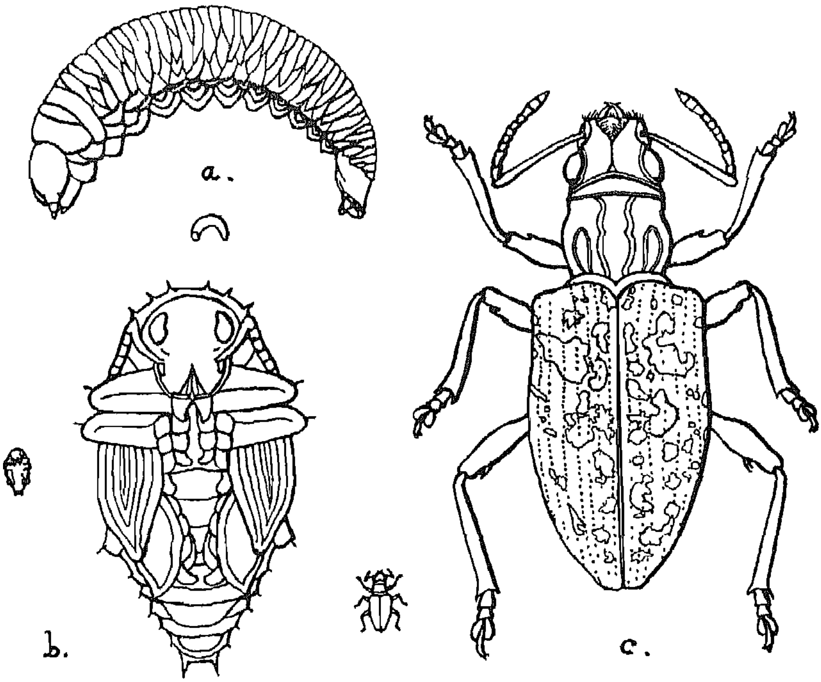

Fig. 89. Myllocerus discolor, beetle (natural size 6 mm.), larva and pupa.

Metialma balsaminae. The larva, length 9 mm., (*tit. cit.*, pp. 14, 15, fig. 65) bores the living stems of *Impatiens balsamina.*

Genus **Myllocerus.** The otiorrhynchine genus **Myllocerus** consists of many species of small weevils, covered with coloured or metallic scales, which feed as adults on the leaves of plants and live as larvae in the soil feeding on the rootlets of grasses and annual plants. The larva is very similar to that of *Cyrtepistomus.*

Myllocerus blandus. The beetle, 3 mm. long, feeds on the leaves of *Dalbergia sissoo*, *Psidium guava* and *Tamarix indica.*

Myllocerus catechu, metallic green, $2\frac{1}{2}$ mm. long, defoliates *Acacia catechu.*

Myllocerus cardoni, the beetle, 4 mm. long, feeds on *Butea frondosa*, *Dalbergia sissoo*, *Flacourtia ramontchi*, *Lagerstroemia* spp. and *Poinciana regia.*

Myllocerus curvicornis. The beetle feeds on the foliage of *Acacia* spp., *Albizzia* spp., *Camellia theifera*, *Casuarina equisetifolia*, *Theobroma cacao*, in Ceylon.

1928, *Journ. Tea. Res. Inst.*, Ceylon, I, p. 46.
1932, *Trop. Agric.*, LXXVIII, p. 138.

Myllocerus discolor, black with fawn and pale markings, 6 mm. long; [Fig. 89 shows the beetle, larva and pupa]. The form **variegata** feeds on *Acacia intsia*, *Dalbergia paniculata*, *Tectona grandis* and fruit trees in new leaf; the larvae feed on the roots of grasses, maize, sugarcane, etc. The form **uniformis** feeds on *Dalbergia sissoo*, *Populus* sp., also on *Aegle marmelos*, *Carica papaya*, *Eriobotrya japonica*, *Mangifera indica*, *Psidium guava*, *Pyrus pashia* and *Zizyphus jujuba*.

Myllocerus dorsatus, the beetle defoliates *Cedrela toona* and *Tectona grandis* in April–July.

Myllocerus echinarius, green, bronzed or darker above, length 3 mm., occurs on teak in Burma.

Myllocerus fabricii, greyish-brown with darker spots, length 5 mm., feeds on *Acacia* spp. and *Casuarina equisetifolia*.

Myllocerus lefroyi, light green, length 3 mm., is a general feeder attacking *Bauhinia*, *Butea frondosa*, *Dalbergia sissoo* and *Prunus cerasus*.

Myllocerus lineaticollis on *Bombax malabaricum*, *Morus* sp.

Myllocerus pubescens defoliates *Cassia fistula*.

Myllocerus sabulosus, the beetle, 5 mm., feeds on *Casuarina equisetifolia*, *Dalbergia sissoo*, *Mangifera indica*, *Shorea robusta* and *Tectona grandis* new foliage.

Myllocerus setulifer, yellowish-green, length 3 mm., is a species that appears suddenly in large swarms (in April in north west India and later further east) on a variety of trees and shrubs including *Dalbergia sissoo*, *Diospyros embryopteris*, *Quercus dilatata*, roses and *Wistaria* causing complete defoliation in a day.

Myllocerus severini, a greyish-brown speckled weevil, length 4 mm., feeds on both the old and young foliage of *Shorea robusta* in Assam and Bengal.

Myllocerus transmarinus, a speckled brownish weevil, length 4 mm., feeds on *Dalbergia sissoo* and *Zizyphus jujuba*.

Myllocerus 11-pustulatus, a greyish-white weevil spotted with black, length 4–6 mm. The form **marmoratus** feeds on *Casuarina equisetifolia*; the form **maculosus** feeds on *Casuarina equisetifolia*, *Dalbergia sissoo*, *Mangifera indica*, *Zizyphus jujuba*, fruit trees and various cultivated plants, and agricultural crops. It is a minor pest of cotton.

The life-history of *maculosus* is recorded by Trehan, K. N., *1929, Agr. Res. Inst.*, Bull. No. 181. Eggs are laid under the surface of the soil; a female may lay 360 in 5 instalments in the course of 3 weeks. The egg hatches in 3 to 11 days. The grub has 4 larval instars in a life of 16 to 35 days, which is passed in the soil feeding on the rootlets of seedlings and young plants. The pupal stage lasts 5 to 7 days. The total life-cycle varies from 35 to 60 days with 5 generations per annum. The cold season, November–March, is passed as a hibernating larva in

the soil and the emergence of the first generation takes place at the end of April. The beetles feed on leaves, ragging them from the edges.

Myocalandra elongata, a Japanese species, breeds in bamboo burrs in Burma.

Myocalandra exarata is a borer of green living bamboo, *Bambusa polymorpha*, *Dendrocalamus strictus* damaged by *Estigmena chinensis*, etc. The eggs are laid in the wounds or tunnels of the primary borers and the larvae mine the weakened internode; the larval galleries run longitudinally in the internodal wall and are not longer than one internode. Emergence occurs in February–June being greatest in April. The larva, 4 mm. × 2 mm., is described by Gardner, 1934, *Ind. For. Rec.*, Ent., XX, ii, p. 40.

Nanophyes dipterocarpi feeds as larva in the seeds of *Dipterocarpus trinervis*.

Nanophyes terminalinae is a pale testaceous weevil with dark dorsal markings, which feeds as larva in the fruits of *Terminalia paniculata* maturing in March–April. The larva is described in 1934, *tit. cit.* pp. 32, figs. 73, 74.

Niphades alni, a hylobiine, bores the wood of *Alnus nepalensis*; adult in September.

Odoacis calophylli, a zygopine, bores the wood of *Calophyllum tomentosum*; adult in May.

Osphilia bombacis, a zygopine, bores the wood of *Bombax malabaricum* emerging in April, May and June–September. The larval characters are given in 1934, *Ind. For. Rec.*, XX, ii, p. 15.

Osphilia gmelinae bores the wood of *Gmelina arborea*.

Osphilia odinae, a small weevil resembling *Phylaitis pterospermi*. It is a borer of the wood of *Bassia latifolia*, *Bombax malabaricum*, *Lannea grandis*, *Mallotus albus*, *Terminalia tomentosa*, *Thespesia populnea*. The generation is normally annual with emergence of the beetles in April and May, particularly in the first half of April. Rarely a small part of the brood emerges during the monsoon, July–October. The larva is described in 1934, *tit. cit.*, p. 15, fig. 67.

Osphilia vitis bores the wood of *Vitis latifolia*.

Osseteris basalis bores the wood of *Heritiera fomes*.

Pachyonyx catechui, length 6 mm., breeds in galls formed on living twigs of *Acacia catechu*.

Pachyonyx quadridens forms galls on the living twigs of *Butea frondosa*. The gall is shaped like a Smyrna fig, with the petiole of one or more leaves growing from its top; an elongate central chamber contains one larva.

Pachytychius viciae is a borer of the living pod of *Vicia sativa*. The larva feeds on the seeds and pupates in the soil; it is described in 1938, *Ind. For. Rec.*, Ent., III, No. 12, pp. 232, 233, figs. 87–89.

Paepalosomus dealbatus is a borer of the twigs and branches of *Boehmeria platyphylla* and *B. rugulosa*; the larval gallery runs in the pith; emergence occurs in June from an exit hole above the pupal cell.

Pagiophloeus levipectus bores the shoots of woody *Lasiococca* in Bengal. The larva, 14 mm., is described in 1938, *tit. cit.*, p. 234 [Fig. 90 shows the beetle).

Pagiophloeus longiclavis, The Mahogany Collar-borer.

Cedrela toona, *Chickrassia tabularis* (?) and *Swietenia macrophylla*. South India to submontane Himalayas and Burma. It has not been recorded from mahogany in Ceylon or Malaya.

This hylobiine beetle is 12–15 mm. long by 4–6 mm. broad, dull black, coarsely sculptured and punctate, with inconspicuous and sparse brown scales; the antennal club is very elongate, longer than the funicle. Fig. 90 of an allied species shows the general appearance. The beetle gnaws the soft epidermis and bast of young shoots; it also feeds on the sap exuding from wounds in the bark and sapwood of large branches and trunks of living or freshly felled trees: the smell of flowing sap attracts it from considerable distances. The beetle is in the habit of travelling far in search of food and suitable egg-laying sites: experimentally marked specimens have been recovered 8 weeks later at 3½ miles from the site of release. The average longevity of the beetles is several months; the longest life recorded is 206 days for a female and 195 days for a male (September to March).

Oviposition: Eggs, 2 mm. long, oval, creamy, are laid singly in wounds on living branches and boles, or in the bark of dying crowns of *Cedrela toona*; they are less frequently laid on injured shoots of *C. toona* or mahogany. In young plantations of *Swietenia macrophylla* the site of oviposition is near the base of stems of living saplings. The female bites a small hole in the bark and enlarges it within to form an oval cavity directed upwards under the concealment of the outer bark; one egg is deposited in each cavity. On thin saplings only one egg may be laid and that always near the collar or ground-level; in larger saplings of 5 inches girth at the base as many as 25 eggs may be inserted within the bottom 18 inches of stem, but the normal number of larval tunnels found in such stems is about 3 to 6. The oviposition-period is prolonged during the life of the female but does not begin until she is about 3 weeks old and may be deferred until 6 weeks old. For one individual it lasts for anything upto 4 months, during which perhaps 200 eggs may be laid; but the average is much less. Eggs of the first brood of the year are laid in May and those of the last brood as late as December.

Larval habits: The egg hatches in 5 days in June–July, 6–7 days in September, and 7–8 days in October. Larvae hatch-

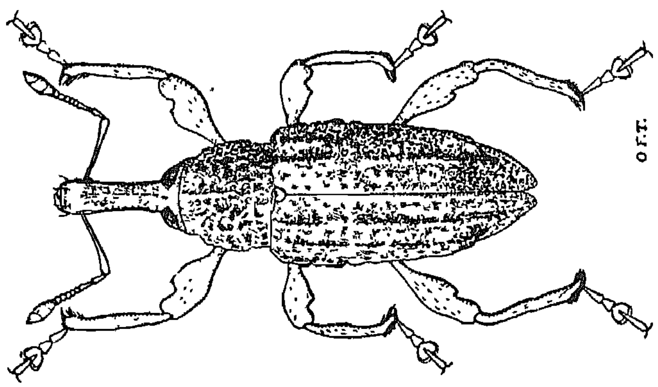

Fig. 90. Pagiophloeus levipectus, male beetle, natural size 9 mm.

ing in a living mahogany sapling start boring in the bast and sapwood making rambling tunnels which are packed with wood-dust and a certain amount of sticky sediment from the sap which may form clots of gum in some places. The reaction of the plant stimulates callus-formation as well as gum-exudation; in a severe fight between plant and larvae the stem swells and cracks in a cankerous collar near ground-level or in patches extending as high as 18 inches above ground or in the rootstock 12 inches below ground: each cankered patch rarely occupies more than 2 or 3 square inches before the plant dies. A vigorous mahogany plant is able to kill a young larva by copious production of gum, and can survive the borer-attack. But a sapling in which a larva developes to maturity almost invariably dies.

The mature larva, 16–18 mm. long, prepares a pupal chamber, about $1\frac{1}{2}$ inches long, directly upwards or downwards from the end of a tunnel running into the heartwood from the surface, and closes it with a plug of coarse wood-fibres. The beetle emerges by retracing the larval tunnel and cutting a circular hole in the outer bark.

Generations: In south India eggs of the 1st generation begin to be laid in May by females that have either (a) hibernated and aestivated as beetles, or (b) emerged early in spring and aestivated. Neither emergence or oviposition occurs in the very dry hot season. A generation may be completed between the 3rd week of May and the 3rd week of July but the rate of development of larvae of this first generation varies widely; the quickest rate produces beetles in a little over 2 months and the slowest not until November and, in addition, abnormally delayed individuals may not appear until during the cold weather. Another generation can be completed between the 3rd week of July and mid

October to the 1st week of November. The third generation in sequence, starting in the period September–November, overwinters and produces beetles in March. Oviposition occurs steadily throughout the monsoon season and the many broods of these generations progressively overlap. As the possible minimum length of the life-cycle is about 2 months it is possible for 3 generations to be completed in one year at the quickest rate of development. But it is probable that the normal development from eggs laid by the 1st generation beetles creates an overwintering population, overwintering in both the larval and beetle stages, i.e., there are normally *two* generations a year overlapping considerably. The emergence-period thus extends over the greater part of the year without marked and regular peaks of abundance. Beetles emerge from dead mahogany plants in all months of the year, sometimes as late as 4 months after its death. The emergence-period of a brood is influenced by the rate of desiccation of the breeding-material as well as the distribution of oviposition; it may extend over 4 months.

Economic importance: *P. longiclavis* is naturally distributed in the range of *Cedrela toona*, but has become notorious in recent years as a pest of young *Swietenia macrophylla* in Madras and Assam-Bengal where plantations of this mahogany have been attempted. It is most injurious in the evergreen areas of the Wynaad and south Coimbatore and the Chittagong Hill Tracts where whole crops have been destroyed but there are plantation-localities from which it is apparently still absent. Plants are attacked most severely in the 2nd and 3rd years of life and less so in the subsequent 2 or 3 years; after the crop has reached an average height of 10 feet, the annual incidence of mortality does not increase but may decrease rapidly and die out in the following year. The abundance of the pest is chiefly determined by the breeding-facilities provided by fellings of *C. toona* nearby; the population produced by breeding inside mahogany plantations is relatively small and unlikely to multiply rapidly without immigrants from outside.

Shade: The liability of new mahogany plantations to collar-borer attack is greater in open sites than in sites with overhead shade given by tree-canopy or by undergrowth or by cover-plants. Deep undergrowth which shelters mahogany plants in clear-felled sites prevents increase of attack more effectively than does the overhead shade of tree-canopy. The protective effect of shade is due partly to physical obstruction to the free progress of the wandering beetles, and partly to slower and stronger growth of the plant. It is possible that shoot-borer attack (due to *Hypsipyla robusta*, Pyralidae), which is more intense on soft rapidly grown shoots, causes lesions and sap-flow which attract the beetle to mahogany plantations; it is possible that transplants injured at

the time of planting out are more susceptible but no correlation has been observed between root-development and liability to attack and mortality.

Dying off: The attacked plant, which is not vigorous enough to kill the borer-larva in its early stage, may die at any time throughout the year, suddenly with a rapid withering of foliage or so slowly that the borer matures and emerges beforehand. On *the whole there is greater mortality in the period* May–December than in November–March of the same biological year; it is greatest in September–December. Recognition of attack from external symptoms is therefore very difficult; three-quarters of the "attacked" plants pulled up in control operations may not contain any living borers.

For control measures see Part Two, Curculionidae.

Gardner, J. C. M., 1934, *Ind. For. Rec.*, XX, ii, p. 25, figs. 27-30 (description of larva).

Pagiophloeus macilentus. The larva bores the wood of *Acrocarpus fraxinifolius*, the beetle emerging in March. It also develops in cultivated apples (the fruit). See *Proc. 3rd Ent. Meet.*, Pusa, 1919, ii, p. 567, 1, p. 210 (Dyscerus fletcheri).

Pagiophloeus malignus. The beetle is brownish-black with a grey patch near apex of the elytra; it feeds on fruits, e.g., apples, acorns of *Quercus* sp., eating small punctures in them and oviposits in small excavations along the edges of such patches. The pearl-white egg is large for the size of the beetle, about 1.25 mm. in diameter. The larva, 12 mm. long, bores in the interior of the fruit and damages it considerably. Pupation takes place inside an attacked fruit which in the initial stage of the attack is externally scarcely distinguishable from a healthy fruit. The food-plants are fruits of *Pyrus malus*, *Prunus nepalensis*, and *Quercus* sp.

Larval characters are given in 1934, *Ind. For. Rec.*, XX, ii, p. 25.
Proc. 3rd Ent. Meet., Pusa, 1919, ii, 567, i, p. 210.

Pagiophloeus umbricidus is reported as injurious to *Grevillea robusta*. The larval food-plants are *Aglaia roxburghiana* and *Cedrela toona*.

Paramecolabus discolor, the beetle rolls the leaves of *Anogeissus latifolia* and *Terminalia paniculata*.

Stebbing, 1914, *Ind. For. Insects*, p. 422, fig. 238 (Attelabus discolor).
Ayyar T. V. R., 1922, *Agr. Res, Inst., Pusa*, Bull. 125, p. 13, pl. IX., fig. 4 (Attelabus).

Paramecolabus feae occurs on *Tectona grandis*.

Paramecops farinosus, a hylobiine, is a borer of the fruit and stem of *Calotropis gigantea* in the larval stage and feeds on the foliage in the beetle stage. The larva, length 10 mm., is described in 1934, *Ind. For. Rec.*, XX, ii, p. 25, fig. 31.

Peltotrachelus albus, a white weevil, ½ inch long, feeds on leaves of *Tectona grandis.*

Peltotrachelus juvencus feeds on *Acacia catechu* foliage.

Peltotrachelus pubes. The beetle feeds on the leaves of *Tectona grandis.*

Pempheres affinis, The Cotton Stem-weevil. Its alternative food-plants are *Hibiscus esculentus, H. rosasinensis, Malvastrum coromandelianum, Sida acuta, S. gentinosa, S. rhombifolia* (Malvaceae), *Corchorus olitorius* and *Triumfetta rhomboidea* (Tiliaceae).

LITERATURE:
Ayyar, P. N. K., 1940, *Proc. 27th Ind. Sci. Congress*, III, p. 168.
Ballard E., 1923, *Mem. Dept, Agr.*, Pusa, Ent., VII, No. 12, pp. 243–255.
Gardner, 1934, *Ind. For. Rec.*, XX, ii pp. 13, 14 (description of larva).
A coloured plate of the life-history has been issued by the Agricultural Research Institute at Pusa.

Peribleptus sculptus the larva bores the living stem of *Girardinia heterophylla.*

The small cylindrical beetles of the campylosceline **Phaenomerus** are associated with shothole borers, *Xyleborus* spp. (Scolytidae) and Platypodidae of about the same size, 2–4 mm. They enter the tunnels of these shothole borers and take possession of them after killing the rightful occupants; this form of aggression is similar to that of *Cyphagogus* spp. (Brenthidae). The larvae are presumed to be woodborers but their tunnels have not been discovered.

Phaenomerus angulicollis in *Albizzia lucida* and *Heritiera fomes.*

Phaenomerus brevirostris in *Butea frondosa, Shorea assamica* and *S. robusta.*

Phaenomerus reclinatus in *Dipterocarpus pilosus, Ehretia acuminata* and *Heritiera fomes.*

Phaenomerus sundevalli in *Albizzia stipulata, Bauhinia retusa, Buchanania latifolia, Butea frondosa, Castanopsis tribuloides, Dalbergia sissoo, Dipterocarpus pilosus, D. turbinatus, Doona zeylanica, Ehretia acuminata, Ficus asperrima, F. glomerata, Heritiera fomes, Machilus odoratissima, Mallotus albus, Mangifera indica, Mesua ferrea, Quercus* sp., *Shorea assamica, S. robusta, Swietenia mahagoni, Terminalia belerica, T. tomentosa.*

The life-cycle appears to be on an annual basis but the emergence-period is prolonged sometimes extending for 12 months, which thus requires an extreme larval life of nearly 2 years. In all the above listed host-trees the presence of *P. sundevalli* is associated with the previous arrival of shothole and pinhole borers of numerous species.

Phloephagosoma aesculi bores the dead wood of *Aesculus indica* and *Alnus nitida,* emerging in May, June.

Phloeophagosoma ficus, a cossonine, bores as larva in the dead wood of *Broussonetia papyrifera, Clerodendron infortunatum, Ficus glomerata, F. roxburghii, Garuga pinnata, Machilus odoratissima, Morus alba, Pinus longifolia.* The life-cycle is annual with a prolonged emergence-period from May throughout the year but predominantly in June, July; stragglers appear 1 or 2 years later.

Phloeophagosoma subcaecum bores the dead wood of *Rhododendron arboreum.*

Phylaitis grewiae, a zygopine, bores *Grewia tiliaefolia, G. vestita* and *Terminalia paniculata;* emergence in May-July and November. The larva, 8 mm. long, is described in 1934, *Ind. For. Rec.*, XX, ii, p. 13, figs. 58–62.

Phylaitis pterospermi, a small beetle with a short body and slender legs; the larva is a sapwood-borer of *Pterospermum acerifolium;* emergence in April, May.

Phylaitis scutellaris is a borer of the wood of *Bauhinia variegata, Cudrania javanensis, Ficus* sp., *Mallotus philippinensis, Morus alba* and *Terminalia tomentosa;* emergence in April, May but there are probably 2 generations.

Phylaitis v-alba is a borer of *Ficus glomerata*; emergence in October, November.

Phytoscaphus fractivirgatus, the beetle is marked with longitudinal dark brown and greenish or golden lines, and defoliates *Tectona grandis* in Assam.

Phytoscaphus triangularis, the beetle feeds on the leaves of *Derris elliptica, Pyrus communis* and *Zizyphus jujuba.*

Platymycterus instabilis, a buff speckled weevil, ¼ inch long, defoliates *Casuarina equisetifolia* in Kanara, destroying the leading shoots of one year old seedlings.

Platymycterus sjostedti, the beetle feeds on the leaves of *Dalbergia sissoo, Mangifera indica,* and *Zizyphus jujuba.*

Plococerus denticollis, a cryptorrhynchine, bores stems of *Euphorbia royleana.* The larva, 18 mm. long, is described in 1938, *Ind. For. Rec.*, Ent., III, No. 12, pp. 247, 248, figs. 15-17.

Protocerius fervidus, the larva bores the stem of living *Phoenix acaulis.* It is a large weevil similar to the following species.

Protocerius grandis, a large dull reddish-brown weevil, over 2 inches long. The large fleshy larva of this species lives in a large chamber formed at the base of the stem of living *Phoenix paludosa* and eventually pupates therein in a cocoon of fibres. The destruction of the palm, which fringes the banks of creeks and estuaries, assists in erosion.

Rhadinomerus acrocarpi, a cryptorrhynchine, bores the wood of *Acrocarpus fraxinifolius,* the beetles emerging in November, December and in April.

Rhadinomerus apicetumens is a borer of the wood of *Rhizophora mucronata,* emerging in April, May.

Rhadinomerus bombacis bores the wood of *Bombax malabaricum;* emergence in January-April.

Rhadinomerus crinipes bores the wood of *Rhizophora mucronata*, emerging in May, June.

Rhadinomerus diversipes, a brown speckled cryptorrhynchine weevil about 1/4 inch long, [fig. 4, No. 24] the larva of which bores the wood of *Anthocephalus cadamba, Eugenia jambolana, Grewia vestita, Machilus* sp., *Mallotus philippinensis, Sapium eugeniaefolium, Shorea assamica, S. robusta, Terminalia chebula* and *T. tomentosa.* The larval gallery is transverse, 1/2 to $1\frac{1}{2}$ inches long, grooved in the sapwood to a depth of about 2 mm. At one end the gallery leaves the surface and penetrates completely into the wood. Pupation takes place in a short longitudinal chamber at right angles to this termination of the larval gallery. The boring is free of wood-dust but long fibres are used to close the pupal chamber. The larva, 7 mm., is described in 1934, *Ind. For. Rec.*, XX, ii, p. 19. There are apparently two generations in the year with emergence postmonsoon in October, November and again in February, and in April, May.

Rhadinomerus elaeocarpi bores the wood of *Elaeocarpus lanceaefolius* and *Macaranga denticulata;* adult in April and November. The larva is described in 1934, *Ind. For. Rec.*, XX, ii, p. 18, figs. 79-81.

Rhadinomerus granulicollis bores the wood of *Amoora wallichii, Anthocephalus cadamba, Litsaea* sp., *Machilus* sp., *Sapium eugeniaefolium, Schima wallichii* and *Terminalia myriocarpa.* Emergence in October-December.

Rhadinomeris machili bores the wood of *Machilus* sp., maturing in March-May and December.

Rhadinomerus maesae bores the wood of *Maesa* sp., *Schima wallichii* and *Terminalia myriocarpa*, emerging in May and November, December.

Rhadinomerus malloti a borer of the wood of *Mallotus philippinensis.*

Rhadinomerus rhizophorae bores the wood of *Rhizophora mucronata,* emerging in April.

Rhadinomerus squamicollis bores the wood of *Sapium eugeniaefolium* and *Terminalia myriocarpa,* maturing in January, February and November.

Rhadinomerus subfasciatus, a borer of the wood of *Erythrina suberosa, Mallotus philippinensis, Schima wallichii, Shorea robusta, Terminalia chebula* and *T. tomentosa.* Emergence occurs with early rains or the onset of the monsoon in April (end) to July (beginning) and the life-cycle is either annual or may possibly be shortened to allow a postmonsoon emergence.

Rhadinopus buteae is a cryptorrhynchine borer of the wood of *Buchanania latifolia, Butea frondosa, Erythrina suberosa, Garuga pinnata, Kydia calycina, Lannea grandis* and *Ptero-*

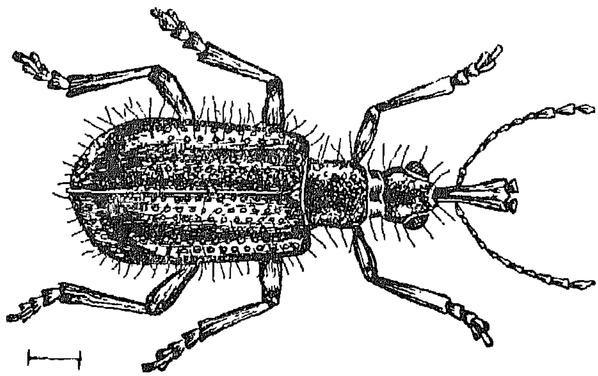

Fig. 91. Rhynchites flavirostris, beetle natural size 6 mm.

carpus marsupium. The emergence-period is premonsoon, May and early June, and the generation is probably annual.

Rhynchaenus mangiferae, the Mango Flea-weevil. The adult is about 2 mm. long and jumps when disturbed. It feeds on young leaves eating patches of epidermis which turn brown and shrivel. Eggs are laid in pockets cut in the leaf-tissue. The larva mines the leaf making narrow irregular tunnels which widen later into blotches. In a heavy infestation one leaf may accomodate 20 to 30 larvae. Pupation occurs in an oval cell within the blotch. The life-cycle is about 12 days in north India. and 10 days in the south.

Hutson J. C. and de Alwis E., 1934, *Trop. Agric.*, LXXXIII, p. 133, coloured plate, 7 figs. (also as leaflet *Dept. Agric. Ceylon)*.

Rhynchites bucklandiae in leaf petioles and stipules of shoots of *Bucklandia populnea*. The female, a bluish-black beetle, 3-4 mm., bites a slit or girdle behind the terminal leaves of shoots up to 1/4 of an inch in diameter; an egg is deposited in a hole in the stem below the girdle and the stem above the girdle drops its leaves and withers. The larva excavates a cavity behind the apex of the shoot in which it feeds and pupates. The beetle emerges in June; it feeds inside rolled up young leaves of *Bucklandia* in July. In nurseries and plantations the damage may become considerable.

Rhynchites canus in fruits of *Berberis asiatica*.

Rhynchites contristatus girdles the soft growing shoots of *Hopea parviflora*, by biting a ring of punctures; the upper part withers and curls over but remains attached until broken off by wind or animals. Eggs are laid in punctured holes in the severed portion; the insect takes from 3-7 months (over the cold season) to reach the adult stage. Pupation may take place in the dried

shoot or in the soil and it is possible that the variation in the length of the life-cycle is dependent on the desiccation and re-wetting of the withered shoot, Emergence of beetles occurs in practically all months but January–March. Similar damage by this beetle is done to shoots of *Jasminum* sp. and *Xylia xylocarpa* in south India. [Fig. 91 illustrates the beetle of a bright green species of *Rhynchites*].

Rhyncholus see **Xenomimetes**,

Rhynchophorus ferrugineus, The Red Weevil of Coconuts.

This weevil occurs throughout the palm-growing districts of India and Burma and in the Malayan region generally and beyond. It breeds in *Areca catechu*, *Arenga pinnata*, *A. saccharifera*, *Borassus flabellifer*, *Caryota urens*, *Cocos nucifera*, *Livistona* spp., *Oreodoxa oleracea*, *Phoenix acaulis*, *P. canariensis*, *P. dactylifera*, *P. sylvestris*.

Life-history: The beetle is about $1\frac{1}{2}$ inches long (including the snout) and varies in colour from very dark red to reddish-brown with traces of up to six black spots on the pronotum. The female lays eggs in wounds or cracks or soft areas in the stem and bases of leaf-stalks of living palms. Sometimes a hole is bored with the snout to a depth of a third of an inch, and the egg is inserted in the hole from the ovipositor. Egg-laying may begin 3 to 5 days after the beetle emerges from the cocoon, and the oviposition-period of one female may last up to eight weeks and as many as 300 eggs may be laid. Eggs hatch in about 4 days in south India. The larva bores into the interior of the palm stem and feeds for about a month. When fullgrown (about 45 mm. × 15 mm.) it constructs a cocoon of long strips of fibres woven into a stout, compact, oval cell. The larva, after shrinking considerably in size, moults and pupates. The pupal stage lasts 2 to 3 weeks and the immature beetle remains another week or 10 days in the cocoon before emerging. The total life-cycle from egg to emergence varies between 50 and 75 days; thus under favourable conditions there may be 4 to 6 generations a year.

Economic importance: The Red Weevil is a serious pest of coconut palms, especially those of four to twelve years old which may be seriously injured or killed. It rarely attacks perfectly healthy palms as for egg-laying it requires wounds such as are made by cutting instruments, animals (porcupines, wild pigs, etc.), diseases, *Oryctes rhinoceros* and wind or lightning. The worst damage is done by the larvae boring in the softer portions of the crown and stem and base of young palms. The attack spreads from original sites of injury until the whole interior of the stem may be riddled by grubs. In the beetle stage the insect does practically no injury to the tree; *R. ferrugineus* occurs throughout India and Burma but not in the Andamans.

LITERATURE:
The Red Weevil of Coconuts, Leaflet No. 22, *Dept. Agr., Ceylon;* and *Tropical Agriculturist*, 1933, pp. 261-265, with coloured plate.
1923, *Dept. Agr. Madras.*, Bull. 86, (biology and control).
Gardner, 1934, *Ind. For. Rec.*, XX, ii, pp. 37, 38, fig. 100 (description of larva).

Sipalus hypocrita. Beetle ½ to 1¼ inches long. [fig. 4, No. 23]. A borer of the wood of *Aesculus punduana*, *Bombax malabaricum*, *Butea frondosa*, *Dalbergia cultrata*, *D. latifolia*, *D. sissoo*, *Kydia calycina*, *Moringa*, *Ostodes paniculata*, *Pinus khasya*, *Pterocarpus dalbergioides*, *P. indicus*, *P. macrocarpus*, *Sterculia campanulata*, *Tectona grandis*, *Wrightia tomentosa*.

Although *S. hypocrita* is polyphagous and widely distributed it is not common and is only occasionally reported as injurious, e.g., to planks and shooks used for packing-cases and to blanks of softwoods used for turnery but the damage is, of course, done in the log. It attacks dying and freshly felled trees often in the company of shothole and pinhole borers. So far as is known eggs are never laid on barked timber. The larval tunnels penetrate deeply into the wood, are circular in cross-section, nearly ½ an inch in diameter at the largest, but varying much in size, usually free of wood-dust, with the walls slightly stained. Coarse long woody fibres are used to make a cocoon for pupation in the larval tunnel. The development and life-cycle have not been studied but it is presumed that one year is required for the normal life-cycle. The emergence-period is prolonged for six months at least and the beetles appear between September and May. The larva, 26 × 10 mm., is described in 1934, *Ind. For. Rec.*, XX, ii, pp. 40, 41, figs. 93–96.

Sphadasmus brahminus makes galls in the living twigs of *Acacia leucophloea*. The old vacated galls are often tenanted by Formicidae.

Sphenocorynes impluviatus breeds in *Alpinia allunghas*.

Stenoscelis gedensis bores the wood of *Pinus khasya*.

Stenoscelis gracilitarsis bores the wood of *Juglans regia* and *Pinus excelsa* in the western Himalayas.

Stenoscelis himalayensis, a black cylindrical cossonine beetle, 3–3.5 mm. long, bores the wood of *Abies pindrow*, *Aesculus indica*, *Alnus nitida*, *Betula utilis*, *Cedrus deodara*, *Picea morinda*, *Pinus excelsa*, *P. longifolia*, *Quercus dilatata*. The larval tunnels are constructed from egg-pits in the mother-tunnel. The larva is described by Gardner, 1934, *Ind. For. Rec.*, XX, ii, p. 35, fig. 111 (as Brachytemnus). This species was originally described as a *Hylastes* and later transferred to *Brachytemnus*. See Stebbing, 1914, *Ind. For. Ins.*, p. 473.

Stenoscelis longifolia, beetle 2.6—3.0 mm. long, bores the wood of *Pinus longifolia*.

Stenoscelis muricatus bores the wood of *Acacia melanoxylon* and *Cupressus macrocarpa* in Ceylon.

Stenoscelis ruptus bores the wood of *Dysoxylum binectariferum.*

Stenoscelis sellatocollis bores the wood of *Abies webbiana.*

Stenoscelis setosus bores the wood of *Abies webbiana* in Kashmir.

Stenoscelis strigicollis bores the wood of *Eurya acuminata* in Burma.

Stereoderus dispar, a cossonine, 4-6 mm. long, bores the wood of *Acacia melanoxylon, Gmelina arborea, Litsaea polyantha* and *Zanthoxylum* sp. The larva, length 9 mm., is described by Gardner, 1934, *Ind. For. Rec.*, XX, ii, p. 34, 35.

Sympiezomias beesoni. The beetle is about 3/8ths of an inch long, black with the sides of the body and the elytral suture green or greyish, more oval in outline than the associated species of *Astycus.* They eat ragged holes usually on the edges but also between the lateral veins towards the midrib of leaves of *Tectona grandis* in south India, [see the diagram of types of feeding-pattern of teak defoliators]. The beetles are very long lived (ten months in captivity) and are most abundant at a period when the teak is attempting to recuperate after defoliation by *Hyblaea puera* and other caterpillars. Egg-laying begins in September and larvae hatch in about ten days. The larval development is presumed to take place in the soil and beetles begin to appear in the hot weather.

Sympiezomias cretaceus feeds on the leaves of *Coffea arabica* and *Morus* sp.

Tanymecus hispidus, the beetle feeds on the foliage of *Dalbergia sissoo* and *Zizyphus jujuba.*

Tetragonothorax macilentus is a borer of *Strobilanthes* sp. in Burma.

Tomicoproctus machili bores the wood of *Dalbergia sissoo* and *Machilus odoratissimus*, the beetle emerging in June, July.

Trigonocolus brachmanae. The beetle is a stout oval weevil about 4-5 mm. long and 2.5 mm. wide, which rings the young shoots of *Butea frondosa, Ougeinia dalbergioides* and *Pterocarpus dalbergioides* by biting holes, and feeds on the sap. Eggs are laid in some of the longer shoots where the girdling is done several inches below the tip. The larva feeds inside the shoot, which withers and falls to the ground, and when full grown it emerges and burrows in the soil for pupation. The larval development is rapid, about one week, and the pupal period lasts 2 to 3 weeks in the monsoon season, during which several generations occur.

The insect is a pest in young pure padouk, *Pterocarpus dalbergioides*, plantations upto three years old, particularly in the Andamans where all the shoots produced during the wet season are cut back when only an inch or two long and a bushy growth results. The seedlings are not much attacked until they reach a

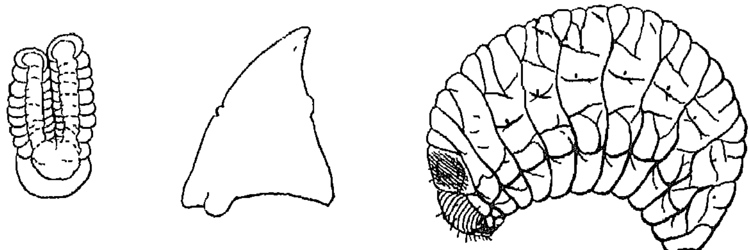

Fig. 92. Xanthochelus blumeae, larva, 10 mm. long; No 38 is the spiracle of the 1st instar, No. 39, the mandible.

height of about 18 inches and from this size until they attain a height of 6 feet they suffer seriously. Damage is worst in open grassy areas and in thoroughly weeded plantations. The damage to padouk is illustrated in Plates XXX–XXXV in Stebbing, 1914, *Indian Forest Insects*, under the name of *Trigonocolus subfasciatus*.

Trochorrhopalus dipterocarpi, a calandrine, bores the wood of *Dipterocarpus alatus*, and *Swintonia floribunda*. The larva, 11 mm. × 4 mm., is described in 1934, *Ind. For. Rec.*, XX, ii, pp. 36, 37. [see fig. 83].

Trochorrhopalus sacchari bores in the stem of *Saccharum officinarum*.

Xanthochelus blumeae. The beetle, a cleonine, is about 12 mm. long. The larva, 10 × 6 mm., lives in soil feeding on the roots of *Blumea wightiana*, and pupates in a cell varnished internally. This is an unusual case of a larva of the Phanerognathi passing its whole larval life in soil. It is described in 1938, *Ind. For. Rec.*, III, No. 12, pp. 236, 237, fig. 37–41 [fig. 92].

Xenomimetes himalayensis, a black elongate cossonine weevil, less than 1/4 of an inch long, bores the sapwood of many conifers, *Abies pindrow*, *A. webbiana*, *Cedrus deodara*, *Picea morinda*, and *Pinus excelsa* and *P. longifolia*. This species was originally described as *Rhyncholus* and later placed in *Eremotes*.

Xenomimetes sikkimensis, a borer of *Evodia fraxinifolia*, *Ilex hookeri*, *Juglans regia*, *Lindera pulcherrima*, *Litsaea citrata*, *Machilus edulis*, *M. odoratissima*, *Mallotus roxburgianus*, *Quercus lamellosa*; adult in most months of the year but emerging chiefly in April to June with a life-cycle of one to two years.

Xerodermus himalayanus, a strombosceine, bores the wood of *Abies pindrow*, *Cedrus deodara* and *Picea morinda*. The beetle feeds on the fruits of *Acer caudatum*. The larva, 5 mm. long, is described in 1934, *Ind. For. Rec.*, XX, ii, pp. 41, 42, fig. 103–105.

Xeroderomus velatus bores the wood of *Cupressus macrocarpa* and an unidentified climber in Ceylon.

Zeugenia gluteae is a borer of the seeds of *Gluta travancorica*. Beetle length 5 to 6 mm.

Zeugenia histrionica, a cryptorrhynchine, bores the wood of *Calophyllum walkeri*, *Dipterocarpus alatus*, *D. (pilosus) macrocarpus*, *D. turbinatus*, *D. zeylanicus*, and *Swintonia floribunda*. Beetles emerge from April to June and are found in the cold season.

DERMESTIDAE

DERMESTIDAE form a small family of oval or oblong beetles, less than 10 mm. long, which are destructive to animal products and animal remains such as skins, hides, horns, wool, fats, cheese, carcasses, etc., also to entomological collections, herbaria and museum exhibits, and to stored grain. The larvae differ completely from those of other Coleoptera; the upper surface is covered with a complex clothing of hairs of various lengths which are often aggregated into terminal or lateral tufts and can be raised or vibrated (Imms). Some are called 'Woolly Bears'.

The life-cycle is adaptable to adverse conditions; the larva and the adult can live for a long time without food and the eggs do not hatch until conditions are favourable for the young larva. The larva moults several times; the hairy moulted skins afford evidence of the presence of the pest. Attacked material may be infested by one generation of Dermestidae for more than a year.

There is no general literature on this family in Indian Journals. Collections were identifid by G. J. Arrow.

For control of Dermestidae and protection of skins, shikar trophies, natural history collections, etc., see Part Two Dermestidae.

Anthrenus fasciatus is one of the Woolly Bears attacking woollen cloth, thread, flock, hair-stuffing, carpet, etc. (wool, hair, pelt or fur of animal origin is destroyed, not cotton wool or material of vegetable origin). The beetle is oval, 1/8th inch long, with white, yellow, red and black mottled markings; the larva is about 1/4 of an inch long with bristly hairs. The life-cycle may be completed in less than a year to over 3 years according to the temperature and humidity of the environment and the amount of food obtained by the larva. (This species is previously mentioned in literature as *A. vorax)*.

Anthrenus subclaviger, a north Indian species, occurs under bark of logs and in rotten wood; it also feeds in the egg-masses of Mantidae *(Hierodula westwoodi)* and on knitted woollen cloths. Beetles of *Anthrenus* frequent flowers.

Dermestes vulpinus. The Skin Beetle, 1/2 an inch long, black above, white below, a cosmopolitan species, breeds in

animal matter such as stored hides and skins, carcasses, meat, cheese, dried fish, mounted shikar trophies, silkworm cocoons, etc. In several countries it causes great losses to the skins and hides industry. It also occurs under bark of logs and the larva has been recorded boring tunnels and cavaties in soft wood of structures in which skins, etc. are stored; but the larva needs food of high protein content with cholesterol which is essential for normal growth,

Thaumaglossa bimaculata and **T. hilleri** feed in the egg-masses of Mantidae.

Trogoderma granarium is a major pest of stored wheat in northern India. (It has previously been recorded under several names *Attagenus undulatus*, *Aethriostoma undulata*, *Trogoderma khapra*, *T. versicolor*).

LITERATURE :

Barnes J. H. and Grove A. J., 1916, *Mem. Dept. Agr. Ind.*, Chem., IV, No. 6.
Fletcher T. B., 1919, *Agr. Res. Inst.*, *Pusa*, Bull 89, p. 29.
Fletcher T. B. and Ghosh C. C., 1919, *Proc. 3rd Ent. Meet.*, *Pusa*, II, p. 712, Control of stored grain pests.
Husain M. A., 1921, *Proc.*, *4th Ent. Meet.*, *Pusa*, pp. 240-248.

Trogoderma nobile breeds in the egg-masses of Mantidae (*Deiphobe infuscata*); also occurs in bored bamboos.

Trogoderma versicolor, a cosmopolitan species, is a pest of entomological specimens in collections; also occurs in stored lac and rice and wheat.

DYTISCIDAE

DYTISCIDAE are a large family of aquatic beetles, sometimes called Diving Beetles, with aquatic larvae. Both the beetle and the larva are carnivorous, feeding on aquatic organisms small or weak enough to be caught and overcome. Species of *Dytiscus*, some of which are over 1½ inches long, may also feed on snails, earthworms, small frogs and tadpoles, fish fry, as well as on aquatic insects, of which the most important economically are mosquito larvae (Culicidae).

Nowrojee D., 1912, *Mem. Dept. Agr. Ind.*, Ent., II, 9, pp. 165-191, 6 pls., Some aquatic Rhynchota and Coleoptera.

Cybister limbatus feeds as beetle and larva on mosquito larvae. A beetle may consume 17 mosquitoes per day.

Eretes sticticus also feeds on Culicidae; an *Eretes* larva may eat 35 mosquitoes a day.

Hydroporus ater. The larva feeds on culicine and anopheline mosquito larvae but not on egg-masses or pupae.

ELATERIDAE.

CLICK beetles, as the adult stages of the ELATERIDAE are propularly termed, resemble the beetles of the Buprestidae in their smooth streamlined form and general appearance, but in larval habits and general ecology the two families are not closely

similar. Elaterid beetles frequent foliage and flowers and soil; if a beetle falls in a reversed position on its back it can spring into the air again through the action of the 'click' structure—a prosternal spine working in a mesosternal groove. In other countries they are known to damage young growing shoots by gnawing the epidermis or biting through stalks and petioles, but no such observations have been made in India.

Elaterid larvae are elongate, cylindrical, tough-skinned forms, some over 2 inches long, with the mouth-parts of predators, legs of active burrowers, and armature of the shovel-head type [see fig. 93] on the posterior extremity.

The habits and food of the larvae are rather diverse but may be roughly classified in three groups,—(a) larva living in soil and feeding on decaying or living vegetable matter, (b) larva living in wood or bark and feeding on wood, and (c) larva living in soil or in wood and feeding on other insects, i.e., predaceous.

In the first group (a) are to be found those species known as 'wireworms' which are (in north America and Europe) injurious to rootlets of seedlings, small plants, grass, etc., and also to large seeds; no genera are definitely recognised as wireworms in India.

The wood-boring larvae (b) belong to genera such as *Lacon*, and *Melanotus*; these are possible but not proved predators. The wood is usually in a decaying or rotten state by the time the end of the life-cycle is reached; ordinarily this takes one year.

The predaceous larvae (c) are represented by species of *Agrypnus* [fig. 93] and *Heteroderes* living in soil, capturing and eating other soil-dwelling insects especially scarabaeid grubs; and by species of *Alaus* living in wood in the tunnels of large wood-borers especially Cerambycidae, the larvae and pupae of which are eaten. *Alaus sordidus* is an important destructive factor at periods of epidemics of *Hoplocerambyx spinicornis*.

Nearly all the literature on the systematics of Elateridae in the Indian region is from the pen of E. Fleutiaux who has published several monographs and faunistic lists.

LITERATURE ON ELATERIDAE:

Chatterjee N. C., 1933, *Ind. For. Rec.*, XIX, v, pp. 7-12, figs. 5, 6, Entomological investigations on the spike disease of sandal (15) Elateridae

Fleutiaux E., 1933, *Ind. For. Rec.*, XVIII, vii, pp. 4-6, Entomological investigations on the spike disease of sandal (10) Melasidae and Elateridae.

Gardner, J. C. M., 1930, *Ind. For. Rec.*, XIV, xiii. p. 283.

Agrypnus fuscipes. The larva [fig. 93] lives in the soil and is predaceous on cockchafer grubs (Scarabaeidae) but also eats caterpillars, lepidopterous pupae and dead insects found on the surface of the ground. The beetle is also predaceous on insect larvae and also feeds on sap. Emergence occurs in May, June and the adult stage is long-lived. The life-cycle is normally annual but may be prolonged in the larval stage for more than 2 years.

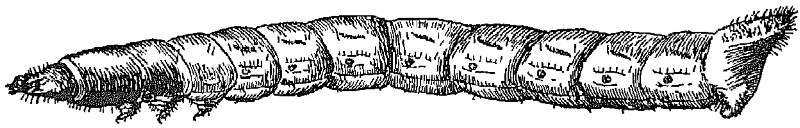

Fig. 93. Larva of Agrypnus fuscipes, natural size 30 mm.

Fletcher T. B., 1919, *Agr. Res. Inst., Bull.* 89, pp. 25-27, figs. 17, 18, Early stages of *Agrypnus fuscipes*.

Alaus anguis in *Artocarpus integrifolia, Bombax malabaricum, Buchanania latifolia, Ficus* sp., *Shorea robusta*, in association with *Belionota prasina*, (Buprestidae), *Hoplocerambyx spinicornis, Macrochenus tigrinus*, etc. (Cerambycidae).

Alaus elaps, A. eryx, A. larvatus, A. nodulosus, A. putridus, A. sculptus and **A. speciosus** are predaceous on wood-boring larvae in numerous species of trees.

Alaus sordidus, in *Bombax malabaricum, Ficus infectoria, Kydia calycina, Shorea robusta, Spondias mangifera,* is predaceous on the Cerambycidae boring these trees.

The beetle is black with dense lichenaceous yellow speckling; it emerges in June–August (over 50 percent in July) with the onset of the monsoon and the life-cycle is annual. Eggs are laid in the bark ejection-holes, etc., of trees attacked by sapwood-borers. In its early stages the larva of *Alaus* attacks the larvae of these borers between the bark and the sapwood; later it makes its way into the deeper tunnels in the wood and into the pupal chambers of the Cerambycidae, where it kills the pupae and immature beetles and uses the pupal chamber of the borer for its own pupation. It is not very abundant ordinarily but increases when there are epidemics of borers and, in the case of *Hoplocerambyx spinicornis*, it may destroy one fifth to one third of the older larvae and pupae. At the end of the life-cycle of *Hoplocerambyx* in May, June about 10–15 percent of its vacant pupal chambers contain living *Alaus sordidus*, indicating that one *Alaus* can destroy 10 *Hoplocerambyx*.

Cussolenis mutabilis lives in decaying wood, e.g., *Anthocephalus cadamba*; its larva is probably predaceous on Eucnemidae. Emergence occurs in April, May.

Dicronychus lacertosus. The beetles frequent foliage of various trees throughout the year in south India, are most abundant in July–September and least abundant in February–April. A graph of the seasonal incidence of the beetles on *Santalum album* is given in *Ind. For. Rec.*, 1933, XIX, v, p. 11, fig. 6.

Heteroderes lenis. The larva, 20 mm. long, lives in soil and is predaceous, eating larvae of Scarabaeidae amongst other diet; the beetle emerges in May–July. The stages are figured in *Agr. Res. Inst., Pusa*, 1919, Bull. No. 89, p. 27.

Lacon modestus lives in the decaying wood of several trees including *Buchanania latifolia, Cedrela toona, Machilus odora-*

tissima, Manihot glaziovii, Mangifera indica. The beetle emerges in June.

The long cylindrical larvae of species of **Melanotus** live in rotten or soft wood and bark of *Bombax malabaricum, Erythrina suberosa, Garuga pinnata, Spondias mangifera, Symplocos theaefolia.* The life-cycle is annual with emergence of beetles in April-June. It is not improbable that these larvae are predators attacking true wood-eating borers. The larva of **Melanotus unicolor,** 30 mm. long, is described by Gardner, 1930, *Ind. For. Rec.*, XIV, xiii, p. 283.

ENDOMYCHIDAE.

MANY of the most conspicuous examples of the Oriental ENDOMYCHIDAE resemble Erotylidae and Coccinellidae in general form and the high development of aposematic (or warning) colouration, and show striking similarities of colour and pattern. Arrow (1925) has monographed about 120 species from the Indian area.

The beetles and larvae feed upon fungi, especially those growing on boughs and on fallen trees. The larvae are broad, flattened, sometimes with spine-like lobes or warts at the side of each segment and are often conspicuously decorated. They pupate gregariously where the rest of the brood is feeding.

LITERATURE ON ENDOMYCHIDAE:

Arrow G. J., 1925, *Fauna Brit. Ind.*, Col., Erotylidae, Languriidae and Endomychidae, pp. 416, figs. 76, pl. 1, coloured.

Ancylopus melanocephalus, 5-7 mm., Europe to Tibet and New Guinea, feeds on decaying vegetable matter in damp places and may be found congregated in large colonies under bark in the cold season.

Eumorphus assamensis and **E. quadriguttatus,** 7-12 mm., are fungus-feeders and also occur in rotten wood and sticks. The larva of *quadriguttatus* is black, flattened, fringed at the sides with spinose appendages, 4 of which are white and 2 are white at the tips only; it feeds with the beetle freely exposed on fungus growing on cut ends of logs (Arrow, 1925, fig. 3).

Mycetina montivaga, 3-4 mm., Himalayas. The larval food is unknown, but the larvae, 14 mm. long, assemble and pupate in the otherwise vacant pupal chamber of a cerambycid (Gardner, 1931, *Ind. For. Rec.*, XVI, iv, pp. 96, 97, figs. 21-25, description of larva).

Trochoideus desjardinsi has an oceanic distribution and seems to be associated with the coconut palm. The beetle occurs under bark of logs, in heaps of refuse, coconut husks, in termite nests and in ant colonies.

EROTYLIDAE

FUNGI such as the *Polypori* and *Boleti* growing on trees, and the agarics or toadstools growing in the soil form the food and habitat of the majority of the EROTYLIDAE; the larvae and the beetles burrow in and eat the fungus and also pupate in it or in the soil without forming a regular cocoon. About 130 species are known from the Indian region. The Languriinae, treated as a separate family by Arrow (1925), are elongate slender beetles of metallic colours. As larvae they are mostly borers in the living stems of soft herbaceous plants, e.g., *Anadastus*, *Coenolanguria* and *Pachylanguria*.

LITERATURE ON EROTYLIDAE:
Arrow G. J., 1925. *Fauna Brit. Ind.*, Col.. Erotylidae, Languriidae and Endomychidae, pp. 416, figs. 76, pl. 1 coloured.
Isaac P. V., 1919, *Proc. 3rd Ent. Meet. Pusa*, pp. 919.

Amblyopus cinctipennis, A. substriatus, A. triplacoides, Aporotritoma jucunda, Aulacochilus oblongus, Dacne indica, Neotriplax rubens and **Rhodotritoma nigricornis** are examples of species that feed as larvae and beetles in fungi growing on bark or on the ground (toadstool) or are found in rotten wood. In the first species the beetle is 4–7 mm. long, the larvae is narrow, elongate without spines on the body and with short paired hooks on the last abdominal tergite.

Anadastus parvulus, a species of Languriinae, is a borer of Italian millet in India; the larva tunnels the hollow stem and rings it above so that the ear withers and the stalk breaks. The complete life-cycle lasts about 50 days (Arrow, 1925, Isaac, 1919).

Caenolanguria nilgirensis bores herbaceous stems and the beetle matures in July, August. The larva is described by Gardner 1931, *Ind. For. Rec.*, XVI, iv, p. 106, figs. 26–28.

Cycloxenus hispidus and **Euxestoxenus striatus** live in the nests of termites, e.g., *Cyclotermes obesus* and *C. brunneus* where they feed in the fungus-gardens.

Pachylanguria cuprea bores living stems of *Impatiens*.

Pachylanguria elongata bores living stems of *Laportea terminalis*.

Tritoma is another erotyline genus of fungus-feeders but **T. praevia** inhabits the decaying bark and wood of *Bombax malabaricum*.

EUCNEMIDAE

FORMERLY included in the family Elateridae and for some time separated under the family name Melasidae, the EUCNEMIDAE form a small group of borers of decaying or rotten wood. Where special collecting has been done numerous species of eucnemids have been found, e.g., 8 species are known from *Macaranga denticulata* in the Bengal Duars, so that it is probable the family is abundantly represented in the Indian region.

The larva is legless and very variable in body-form: depressed with parallel sides or buprestiform or fusiform. The head is small and highly specialised with dorsal and ventral hard plates usually angulate in the middle behind; it is provided with mandibles suitable for fraying wood but there is no apparent mouth-opening through which anything but liquids could enter. Gardner notes that the ventral mouthparts are specialised for liquid sucking and have in fact some resemblance to those of ticks: there is evidence that wood is the source of food for many species, although wood-fragments have rarely been found in the alimentary canal; there is no evidence that any are carnivorous. They occur in soft or hard dead wood and make definite tunnels or cells; pupation occurs in the wood or between bark and wood.

The life-cycle is annual with emergence usually in the dry season March–May, but some species mature during the monsoon (*Fornax vestitus*).

Fleutiaux is the authority on the systematics of the family in the Indian region.

LITERATURE ON EUCNEMIDAE:

Fleutiaux E., 1926, *Ind. For. Rec.*, XII, x, New species of Fornax from India, Melasidae.

— 1930, *tit. cit.*, XIV, vi, pp. 153, 154, Two new species of Coleoptera from India.

— 1930, *tit. cit.*, XIV, xi, pp. 273, 274, A new genus and a new species of Melasidae and a new species of Elateridae.

— 1933. *tit. cit.*, XVIII, vii, pp. 1–16, Entomological investigations on the spike disease of sandal (10), Melasidae and Elateridae.

— 1934, *Rec. Ind. Mus.*, XXXVI, iii, pp. 327, 328, Three new Indian species of Eucnemidae.

Gardner J. C. M., 1926, *Ind. For. Rec.*, XII, x, pp. 3–8, Description of the early stages of *Fornax gardneri*.

— 1930, *Ind, For. Rec.*, XIV, xiii, pp. 281, 282, Immature stages of Indian Coleoptera (7).

— 1935, *Ind. For. Rec.*, Ent., I, No. 4, pp. 79–91, 29 figs., Immature stages of Indian Coleoptera (17) Eucnemidae.

Adelothyreus bengalensis bores the decaying wood of *Anthocephalus cadamba* and *Macaranga denticulata*. The beetles emerge in March, April. The larva, length 15 mm., is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I, No. 4, p. 88, figs. 8, 9.

Arhipis balwanti bores the decaying wood of *Macaranga denticulata* and other species, beetles emerging in April. The larva, length 5 mm., stout and fusiform, is described by Gardner, 1935, *tit. cit.*, p. 90, figs. 24, 25.

Arhipis orientalis bores the decaying wood of *Anthocephalus cadamba* and *Macaranga denticulata* and other species, beetles emerging in April. The larva, length 7 mm., is described by Gardner, 1935, *tit. cit.*, p. 89, figs. 19–21.

Arisus bituberculatus bores *Macaranga denticulata*, beetles emerging in April. The larva, length 12 mm., is described by Gardner, 1935, *tit. cit.*, p. 87, figs. 16–18.

Dendrocharis intermedia bores the wood of *Shorea robusta*, maturing in April.

Fornax ? birmanicus bores the wood of *Anthocephalus cadamba*, beetles emerging in April.

Fornax carissae bores the decaying wood of *Carissa spinarum*.

Fornax distinguendus bores the decaying wood of *Sterculia campanulata* and other species, beetles emerging in May, June. The larva is described by Gardner, 1935, *tit. cit.*, p. 86, figs. 5, 6.

Fornax gardneri bores the decaying wood of *Carissa spinarum* and woody climbers. The egg, larva and pupa are described by Gardner, 1926, *Ind. For. Rec.*, XII, x, pp. 273–280, figs. 8–16.

Fornax ? nitidus bores the wood of *Pterocarpus dalbergioides* emerging in April.

Fornax superbus bores the wood of *Macaranga denticulata*.

Fornax vestitus bores the wood of *Bombax malabaricum*, *Garuga pinnata*, *Lannea grandis*. Emergence of beetles occurs in June–October but mainly in August; the life-cycle is annual with swarming and oviposition during the monsoon season, unlike the majority of species of Eucnemidae which emerge in the dry hot weather, March–May. The larva, length 27 mm., elongate, parallel-sided, with a serrate head and a rounded 9th abdominal segment, is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I, No. 4, p. 85, figs. 1, 2.

Galbimorpha agastoceroides bores the decaying wood of *Anthocephalus cadamba* and *Macaranga denticulata* emerging in the cold season, January–March. The larva, length 11 mm., stout and fusiform, is described by Gardner, 1935, *tit. cit.*, p. 91, figs. 27–29.

Hodocerus malaisiensis bores the wood of *Pentacme suavis* emerging in May.

Melasis balwanti bores the wood of *Gynocardia odorata*, emerging in April. The larva, length 23 mm., elongate, cylindrical, slender, is described by Gardner, 1935, *tit. cit.*, p. 83, figs. 14, 15.

Phizoschilus gardneri bores decaying wood of *Cedrus deodara* and *Machilus odoratissima* in the Himalayas. Emergence occurs in April. The larva, length 14 mm., and pupa are described by Gardner, 1930, *Ind. For. Rec.*, XIV, xiii, pp. 281, 282, figs. 8–11.

Poecilochrus bengalensis bores the wood of *Anthocephalus cadamba* and *Macaranga denticulata*. Emergence occurs in April. The larva, length 23 mm., is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I, No. 4, p. 87, figs. 10–13.

Pseudoscython parvulus bores the decaying wood of *Anthocephalus cadamba*, *Macaranga denticulata* and other species. Emergence occurs in April. The larva, length 9 mm., is described by Gardner, 1935, *tit. cit.*, pp. 88, 89.

Pterotarsus fulvus bores the wood of *Crataeva ? unilocularis*, emergence occurring in May, June.

Scopulifer atkinsoni bores the wood of *Pentacme suavis* emerging in May.

GYRINIDAE

WHIRLIGIG Beetles or GYRINIDAE are aquatic in all their stages. The diet of the beetles is mainly vegetable-matter but dead or drowning insects are also eaten. The larvae (which have tracheal gills and thus derive the air they breathe directly from the water in which they live) are primarily carnivorous and predaceous feeding on small aquatic organisms including larvae of mosquitoes (Culicidae) and bloodworms (Chironomidae).

The larvae of species of **Dineutes** and **Orectochilus** catch and eat mosquito larvae. The beetle of *Orectochilus* also feeds on mosquito larvae taking as many as 10 a day.

Ochs G., 1930, *Catalogue of Indian insects*, Part 19. Gyrinoidea, pp. 39.

HISTERIDAE

MOST beetles of the HISTERIDAE are characterised by hard polished and striate integument, usually black, together with ability to withdraw the limbs, and generally also the head, behind the unbroken smooth surface of the body; in some countries they are known as steel beetles. It is a large family of perhaps 2,000 described species. The body-form is appropriate to the burrowing agressive life of a predator or a scavenger but its general outline shows various modifications according to the environment and associates. Those species that burrow in dung, carrion, and decaying matter and are predaceous on the larvae of other insects living in the same habitat are more or less hemi-spherical, e.g., *Hister*, *Saprinus*. Those living in the tunnels of bark-borers are oval and less convex, e.g., *Platysoma* in tunnels of Rhynchophora; others tend to be more cylindrical, e.g., *Teretrius* and *Teretriosoma* in galleries of Bostrychidae; while extreme cylindrical forms are exhibited by some beetles of *Niponius* which work in the tunnels of bark-boring Scolytidae. On the other hand extremely flattened dilated thin bodies suitable for squeezing between bark and sapwood are characteristic of *Hololepta*. Some genera live in nests of termites or ants.

The life-histories of Indian Histeridae have not been studied and the life-cycle has not been determined. By analogy it is supposed that the beetle lays its eggs while foraging in the tunnels of borers. The histerid larva is softer and shorter-legged than that of the general staphylinoid type; it is evidently accustomed to a diet of living or recently dead animal-tissue and rarely resorts to plant-remains as a secondary source of food. The larva of *Niponius* is an elongate slender cylindrical form with quite short legs, which shews all the essential characteristics of the Histeridae (Gardner). Neither larva or beetle of a predaceous species of

Histeridae appears to be particularly selective in its prey; it feeds on other insects such as clerids, staphylinids, parasitic hymenoptera, diptera, etc. which form part of the life-community of the true borers.

LITERATURE ON HISTERIDAE:

Fowler W.W., 1912, *Fauna Brit. Ind.*, Col., General introduction, pp. 91-94, figs. 44-46 (families Histeridae and Niponidae).

Gardner J. C. M., 1925, *Ind. For. Rec.*, XII, vii, pp. 193-198, fig. 1 a-f, pl. 1 figs. 1, 2, Descriptions of new species of Niponiidae and Cerambycidae from India.

— 1935, *Genera Insectorum*, Col. Histeridae, subfam. Niponiinae.

Stebbing E. P., 1914, *Ind. For. Ins.*, pp. 101-107, figs. 66-70.

Cylistosoma dufali is a predator of bark-beetles (Scolytidae) particularly of conifers in the Himalayas.

Hister spp. Several species of the black polished convex beetles of *Hister* inhabit cattle dung feeding on larvae of flies and beetles inhabiting dung, e.g., **H. chinensis, coelestis, daldorffi** and **orientalis. H. gardneri** occurs in fungus; **maindroni** in carrion; and **pustulatus** and **sexstriatus** attack larvae of *Agrotis ypsilon* (Noctuidae).

Hololepta spp. are black polished but very much flattened beetles able to squeeze between the bark and wood of borer-attacked logs. **H. baulnyi, elongata, indica** and **laevigata** occur in the bark of trees attacked by Cerambycidae, Curculionidae and Scolytidae.

Niponius andrewesi, 4.5 mm., is one of the relatively stout species of *Niponius;* it is predaceous in the tunnels of Scolytidae which bore in thick barked trees, e.g., of *Sphaerotrypes siwalikensis* in *Shorea robusta.* Its larva is white, very slender and cylindrical, each abdominal segment with ambulatory ampullae, the thorax with very short legs, the head strongly depressed and exserted (figured by Gardner, 1935, figs. 1–6). The life-cycle appears to be short in conformity with that of its scolytid prey; the emergence-period is sharply defined rarely extending over more than two months and without delayed individuals, which suggests that the beetle stage must be long-lived and disperses freely. In cages the maximum emergence occurred in April–June; it is a common species but not an overwhelmingly destructive enemy of *Sphaerotrypes.*

Niponius bicolor, 2.7 mm., (see Gardner, 1935, for description and figure) a black and red species, occurs in the Andamans associated with *Cryphalus* sp. (Scolytidae).

Niponius canalicollis, 4 mm., is predaceous on bark-beetles, *Ips, Polygraphus,* of conifers in the Himalayas. The emergence-period extends from June to August.

Niponius himalayensis has similar habits (Gardner, 1926, fig. 2).

Niponius parvulus, 2 mm., is predaceous on *Cryphalus* spp. in the peninsula of India.

Niponius punjabensis, predaceous on *Polygraphus* spp. in the Himalayas (see Gardner, 1925, fig. 1 and description).

Niponius substriatus, 3.3 mm., predaceous on *Cryphalus* sp. in the Himalayas (Gardner, 1925, p. 197).

Niponius variabilis, 3-4 mm., on *Hylesinus* sp. (Scolytidae) in Peninsular India (Gardner, 1925, p. 197).

Platysoma spp. also occur as predators in borer-attacked logs. **P. atratus, borneolus, brahmani, cambodjensis, confucii, odiosus, pangami, strialis** are associated with bark and sapwood borers, i.e., Anthribidae, Curculionidae, Scolytidae, etc. in many species of trees. The smaller beetles, e.g., of Scolytidae, are captured also outside the tunnels on the bark by beetles of *Platysoma*.

Saprinus spp. feed on carrion and the larvae of flesh-flies, e.g., **S. chalcites, semistriatus, speciosus.**

Sitalia severini and **Spalthochirius termitophilus** occur in termites' nests.

Teretriosoma intrusum and **T. stebbingii** are predaceous in the tunnels of Bostrychidae in many species of trees. Emergence occurs from logs throughout the year but preponderantly in June, July.

Teretrius indus and **T. mogul** are predaceous in the tunnels of bostrychid borers of bamboo, primarily *Dinoderus* spp.

Teretrius picipes is predaceous on *Lyctus brunneus* and *L. fuscus* (Bostrychidae).

Trypeticus beesoni, T. indicus and **T. veda** are predaceous on shothole borers, *Xyleborus* spp. (Scolytidae) and Platypodidae.

HYDROPHILIDAE

COMPOSED almost entirely of Water Beetles with aquatic larvae the family HYDROPHILIDAE is of minor importance in the forest biome; but some genera of the Sphaeridiinae are terrestrial in all stages. The larvae of the Hydrophilinae are essentially carnivorous.

Dactylosternum hydrophilioides. The beetles occur in fermenting plant-tissue such as the dead bark of many species of trees throughout India and Burma, decaying stems of *Carica papaya* and *Musa sapientum*, elephant dung, etc. In banana stumps its larvae are predaceous on the grubs of the banana borer *Cosmopolites sordidus* Curculionidae, (Corbett, 1936).

LITERATURE ON HYDROPHILIDAE:

d'Orchymont A., 1923, *Mem. Dept. Agr. Ind.*, Ent. Ser., VIII, pp. 12, Hydrophilidae of India. A list of the species in the collection of the A.R.I., Pusa

— 1928, *Catalogue of Indian Insects*, Part 14, pp. 146, Palpicornia.

Nowrojee D, 1912. *Mem. Dept. Agr. Ind.*, Ent. Ser., II, 9, pp. 165-191. 6 pls. Some aquatic Rhynchota and Coleoptera.

IPIDAE see SCOLYTIDAE

LAGRIIDAE

CLOSELY allied to the Tenebrionidae but retained as distinct chiefly because of larval differences. Beetles of the LAGRIIDAE are seen on foliage of shrubs and trees, and occur under bark and in the shelter of debris on the ground. The life-histories are not known. Beetles of the genus *Lyprops* assemble in large numbers and invade houses.

There is no literature in Indian journals except for the references given under the following species.

Lagria spp. Beetles occur on foliage and in soil debris; the larvae live in the soil.

Lyprops curticollis is a pest in bungalows on rubber estates in Malabar. In March, April the beetles assemble in large swarms and migrate to buildings. On arrival they settle on whitewashed walls in millions but by morning have secreted themselves in cracks in the woodwork. In the evenings for the first month or two, they come out in myriads when the lamps are lit, but are less active later in the season and remain dormant except when heavy showers disturb them. They are definitely attracted to light. No signs of damage by feeding have been observed. When a beetle is squeezed against the human skin an irritating fluid is exuded. The life-history is not known but the larval stages are probably passed in vegetable refuse or in humus soil. It is possible that abundance of a particular kind of waste matter or by-product of rubber cultivation allows exceptional multiplication of the insect.

Lyprops indicus. The larva has been found living in soil under stones and pupating in January, February; the pupal period lasts one to two weeks. The larva, 11 mm., and pupa are described by Gardner, 1929, *Ind. For. Rec.*, XIV, iv, pp. 125-127, figs. 19-26 (as Tenebrionidae). Beetles which have been sheltering under the bark of logs, etc. leave them in the autumn; there is possibly a short life-cycle during the cold season.

LAMPYRIDAE

FIREFLIES and glow-worms are found throughout the world in in over 2,000 species constituting the family LAMPYRIDAE. They are nocturnal insects distinguished by the possession of photogenic organs or tissues in some or all stages of most species; the egg, larva, pupa and adult all may be appreciably luminescent. The winged adult male is a 'firefly'—the wingless adult female is a 'glow-worm'—a larva of similar appearance is also a glow-worm. Taking uniformity of structure in the sexes as a criterion, the primitive condition (a) is found in those genera in which both sexes have the wings and elytra of normal size and function and have the light-producing organs slightly developed or absent; (b) then there are genera in which both sexes are winged and luminescent

but the luminescent patches are more developed and brighter in the agile flying male ;.(c) the wings of the female are reduced or absent and those of the male are shortened but functional *(Lampyris,* [fig. 94], *Luciola); (d)* the wingless female is much larger (3-times) than the short-winged male, and produces a more brilliant glow ; sexual dimorphism also occurs in the larval stage (*Lamprophorus*). With this loss of the ability to fly and the evolution of a more brilliant light in the female there is a corresponding improvement in the vision and antennal perception of the male of the species.

Life-cycle: The large eggs are laid in the soil and in some cases protected by the female till hatched. The larvae are of the blattoid type, carnivorous, feeding on soil-dwelling organisms from snails and worms to small insect life. Pupation takes place in a cell in the soil or in rotten wood, etc. The adults take little or no food but the males frequent flowers for droplets of water and some females are cannibalistic. Very little is known of the length of life-cycles; *Lamprophorus* takes a year; other genera may require two years.

Fireflies: The fireflies are beetles of the genera *Diaphanes, Lamprophorus* and *Luciola* and may be seen at night flying about in trees and low jungle particularly in the rains. The luminous area is on the ventral surface of the abdomen extending over the two posterior segments in the female and three in the male. Cunningham describing fireflies in Bengal records ". . . The steady flame of the greenish lamps of glow-worms is undoubtedly very beautiful, but it cannot compete in charm with the effects produced by the intermittent flashing of the lights of myriads of fireflies swarming amid heavy masses of foliage or wandering fitfully round through the black air of a still and moonless night . . . It was usually during the rainy season that the finest displays took place, but all throughout the winter and summer months scattered lights were to be seen . . . unless on occasions when the weather was exceptionally dry or cold. In winter fireflies would sometimes almost entirely vanish for a time but on any slight rise in temperature they were ready to reappear, and a brief fall of rain was all that was needed to secure a general resurrection . . . Occasionally during the rainy season whole trees are tenanted by myriads of flashlights, and all the air around alive with floating sparks."

Nature of the luminescence: The light in fireflies and glow-worms consists wholly of visible rays with no infra-red or ultra-violet heat rays and none of the energy is lost in the form of heat. It is practically a perfect cold light and compared with artificial lights has an efficiency of nearly 100 percent. In a gas flame only 2 percent of the energy is converted into light rays; in the electric arc 10 percent; in sunshine 35 percent. The

luminous organ contains a photogenic layer of cells richly supplied with tracheae which form a dense network containing a granular substance of fatty nature. It is the instantaneous oxidation of this substance (*luciferin*) in the presence of water that produces the luminosity. The production of light is controlled by the insect; the glow-worm shows a light for an appreciably long period; the firefly flashes intermittently. On some occasions a remarkable synchronism occurs in a swarm of fireflies, thousands of individuals flashing exactly in unison with regular intervals of darkness. Synchronous flashing may be built up in a swarm from the signals initiated by a single pair of insects. The female responds to the flash of a male after a regular interval and other males originally out of phase readjust themselves to the rhythm of a communicating pair.

The object of the light is not explained. It may be for defence, allurement, illumination, recognition, and in some species is certainly for sexual purpose. No commercial use has been made of these light-producing insects but they may serve in the artificial synthesis of luciferin which would give to the world an illuminant far more efficient than the best artificial lights of the present day.

LITERATURE ON LAMPYRIDAE:

There are no general monographs or catalogues in Indian periodicals. References are given under species.

Cunningham D. D., 1907, *Plagues and pleasures of life in Bengal*, pp. 127-130.

Lamprophorus tenebrosus. The Indian Glow-worm.

This species is luminescent in all four stages—egg, larva, pupa and beetle. The male beetle is a 'firefly' and the female beetle is a wingless 'glow-worm'. The male, 20–30 mm. long, has a black head, brown pronotum and elytra, the latter soft and shorter than the abdomen. Light is emitted from 2 whitish patches on the underside of the end of the abdomen. The female, 2½ inches long, is a pale, yellow, wingless beetle resembling its own blattiform larva. Its luminous areas are situated near the hind end of the abdomen of which the last segment is furnished with a protrusible and retractile organ composed of clusters of thread-like processes. This organ is used in locomotion and for cleaning.

Life-cycle: The spherical yellow eggs, 4–5 mm. diameter, are laid in a burrow made by the female in batches of 30–100; the oviposition-period lasts for 1-3 weeks and is immediately followed by an incubation-period of 4–13 weeks during which the female continuously broods over her eggs. The larva are active in all stages feeding chiefly at night and sheltering under stones and fallen leaves by day. A full grown larva is 65–80 mm. and is shiny black with brownish-yellow margins. It is a glow-worm with luminous areas toward the tail end and also a cleaning organ as in the adult. There are 3 instars in the male larval stage and 5 or 6 in the female; the larval period lasts 8 or 9 months. Pupation takes place in a burrow or cell in the soil; the pupal

period lasts 16–23 days for the male and 7–10 days for the female. The total life-cycle is thus about a year.

The glow-worm larva feeds on snails and frequents damp places and wet plants in the rainy season when snails are abroad. It takes about two hours to eat a snail, cleaning out the whole body from inside the shell and a large glow-worm may eat 6 small snails a day; during a whole larval life 20–40 snails are eaten by one male larva and up to 60 by one female. It is a useful enemy of the African or Kalutara snail *(Achatina fulica)* which was introduced into India, Ceylon (1900) and the Malay Peninsula (1922).

Luminosity: The luminous areas of the female are brighter than those of the male but they light up only when the female is disturbed or excited, as when calling the male before pairing. The female may sometimes be found at dusk in vegetation, sitting curled up on the ground with the tail erected so as to expose her light to best advantage. Males fly up with a loud buzzing but without lights and drop close to her. When pairing the female uncurls and the lights die down to a faint ventral glow. The male luminosity is also controllable but in the form of flashes (see ante page 307).

LITERATURE:

Austin G. D., 1924. *Trop. Agric.*, pp. 68, 69, pl. XXVI, The Indian glow-worm, Lamprophorus tenebrosus.

Hutson J. C. and Austin G. D., 1924, *Ceylon, Dept. Agr.*, Bull. No. 69, pp. 1-24, pl. 1, Notes on the habits and life-history of the Indian glow-worm. An enemy of the African or Kalutara snail.

Paiva C. A., 1919, *Rec. Ind. Mus.*, XVI, pp. 19-28, pl. viii, Notes on the Indian glow-worm, Lamprophorus tenebrosus.

Lampyris marginella. The beetle and pupa of this firefly are shown in fig. 94; the larva is 15 mm. × 2·25 mm. *(Agric. Res. Inst., Pusa.*, Bull. 89, pp. 27, 28, fig. 22).

Luciola spp., The males are testaceous-yellow and black beetles, 5–10 mm. long, with very large eyes, and long elytra, abundant at night as fireflies in shrubs and jungle. The females are uncommon, have small eyes, and produce a feeble luminescence; they frequent the surface of the ground and the soil-cover and rarely fly. The larvae, 20 mm. × 4 mm., are glow-worms, and feed on dead worms, small molluscs and insects such as lepismids (Thysanura). **L. gorhami, dubia, chinensis** and others are common species.

LITERATURE:

Bugnion E., 1922. *Spol. Zeylan.*, XII, pp. 1-14, pls. 2, Luciola nicollieri sp. n. de Ceylon.

Mehta D. R., 1932, *Bull. Dept. Zool., Punjab Univ.*, I, pp. 101-118, pls. 3, Fauna of Lahore. 3. Preliminary notes on the life history of the firefly Luciola gorhami Rits. and cytology of the light organs.

Anon. 1919, *Agric. Res. Inst., Pusa*, Bull. 89, pp. 28, 29, fig. 21 (Larva of Luciola gorhami).

LANGURIIDAE see EROTYLIDAE

LARIIDAE see BRUCHIDAE

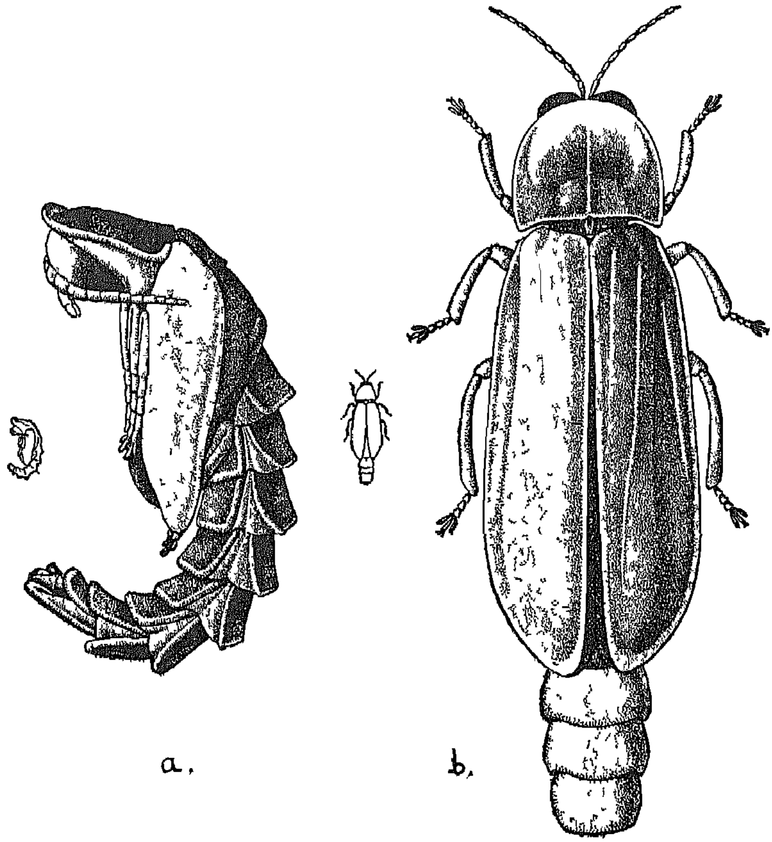

Fig. 94. Lampyris marginella, beetle and pupa (small figures are natural size).

LATHRIDIIDAE

IN the small family of LATHRIDIIDAE (allied to the Mycetophagidae) which comprises minute beetles living under bark, in rotten wood and fungi there is only one species needing mention.

Holoparamecus kunzei is very common under the bark of logs attacked by borers of all sorts but in what role is unknown From caged logs of many species of trees attacked by borers the beetles of *H. kunzei* emerge after a long period extending for over 2 years. The life cycle requires one year or more, the emergence of the beetles takes place between April and November and is at its maximum abundance in September–November. The long larval period and the concentrated maturation of the beetles suggests the life-cycle is influenced by the progress of decay of the bark or sapwood, which decay is dependent on seasonal weather.

LUCANIDAE

MALES of the larger species of LUCANIDAE have mandibles unusually developed and resembling the antlers of deer, a feature that centuries ago earned these beetles the popular name of Stag Beetles in several languages. A Stag Beetle is the subject of a famous etching of Albrecht Durer made in 1505. The largest known beetles, tropical species over 4 inches long, belong to this family: nevertheless many species of Lucanidae are small and the mandibles of the male are not conspicuously larger than those of the female. They occur in the forests of the high Himalayas and in the moister hill forests of the tropical districts. The larvae live in decaying or soft wood of logs and stumps which remain continually moist or almost sodden with water. They do not bore in hard wood, or in either green or properly seasoned wood. The larva is a fleshy strongly curved grub [fig. 95] which eats out broad irregular tunnels in the decayed soft wood, filling them with shredded fibres and faecal pellets. Larval life lasts at least one year and may take 2 or more years in cold climates. *Pupation takes place in the loosely shredded debris of wood.*

The larval mandibles have strong molar developments and the hypopharynx has a heavy sclerome; together these form a strong grinding apparatus for the mastication of the soft decaying woody tissue and the fungus impregnating it, which forms the food. Larvae have been described by Gardner, 1935, and Gravely 1916.

Lucanidae are quite important agents of destruction of dead trees in regions where termites do not occur. A few species are injurious to the flowers of trees in the tropics. A monograph on the family in the *Fauna of British India* series is in preparation by G. J. Arrow.

LITERATURE ON LUCANIDAE:

D' Abreu B. A., 1915, *The Beetles of the Himalayas.*

Gardner J. C M., 1935, *Ind. For. Rec.*, Ent. I, No. 1, pp. 6-8, figs. 6-12, and 76.

Gravely F.H , 1916, *Rec. Ind. Mus.*, XII, 145-150, pls. xxi, Lignicolous beetle-larvae.

Cladognathus giraffa occurs in the Himalayas and Assam-Bengal hill ranges living in decaying wood, e.g., in *Mangifera indica*, *Picea morinda*, *Quercus* spp. The beetles mature in May–August (mainly May) and the life-cycle may be prolonged for two years.

Dorcus antaeus in the wood of *Quercus incana.* The larva of *Dorcus titanus* is described by Gardner, 1935, p. 8, fig. 9.

D. rugosus in the wood of *Juglans regia.*

Eurytrachelus reichei in the wood of *Betula cylindrostachys*, *Castanopsis tribuloides*, *Rhododendron* sp. In Java beetles of *Eurytrachelus* eat the flowering spikes of coconut palms and the flower-clusters of coffee. The pupa of a *Eurytrachelus* is described by Gardner, 1935, p. 7, fig. 75.

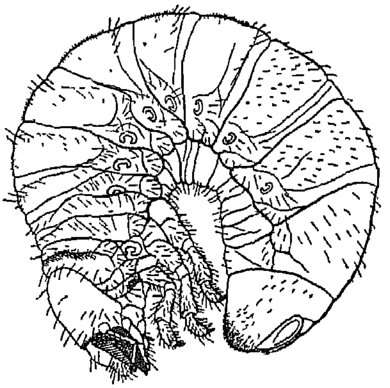

Fig. 95. Larva of Hemisodorcus donckieri, natural size 50 mm.

Hemisodorcus donckieri in the wood of *Machilus odoratissima*; the larva, 50 mm., is described by Gardner, 1935, p. 8, fig. 6 [see fig. 95]. **H. macleayi** in the wood of *Ficus nemoralis*. **H. nepalensis** in the wood of *Aesculus indica*, *Betula utilis*, *Cedrus deodara*, *Quercus dilatata*.

Lucanus cantori in the wood of *Betula cylindrostachys*, *Castanopsis tribuloides*, *Symplocos theaefolia*. **L. lunifer** in the wood of *Quercus dilatata* and *Q. incana*. **L. mearssi** in the wood of *Symplocos theaefolia*.

Melopodontus biplagiatus in wood of *Mangifera indica* and *Sapium sebiferum*. The larva, 35 mm., is described by Gardner, 1935, p. 8, fig. 7 (as *Prosopocoelus biplagiatus*).

Nigidius distinctus in wood of *Macaranga pustulata*.

Prosopocoelus budda in wood of *Picea morinda*.

LYCIDAE

THE beetles of the malacoderm family LYCIDAE are diurnal, frequenting foliage. The sexes in most genera are similar with primary coloured soft elytra stiffened by reticulate ridges but in some there is a well developed dimorphism. Some lycid beetles are supposed to be phytophagous but without clear evidence. According to Kleine who has studied and named recent Oriental collections, this family is poor in genera but the genera are mostly rich in species; moreover genera and species can be characterised only very obscurely and pass into one another.

The larvae are of a blattoid type with flattened, expanded or lobed sides to the thoracic and abdominal segments; extreme forms of this type are known as trilobite larvae. Many species of these trilobite larvae have been discovered but in very few cases have they been associated with adults; it is possible that the female beetle of some genera (e.g., *Lyropaeus*) is wingless and specialised like a large trilobite larva.

The biology of this group is unknown; possibly the larvae feed on molluscs or planarians but it is not definitely observed; or on wet decaying wood, e.g., *Calochromus*, for probably all lycid larvae have suctorial mandibles able to ingest the moisture in decaying wood. Pupation in some genera is gregarious; late comers assemble around a nucleus of early arrivals so that larvae, pupae and young beetles may be found together.

LITERATURE ON LYCIDAE:

Fowler W. W., 1912, *Fauna Brit. Ind.*, Coleoptera. General introduction, pp. 135, 136, figs. 57, 58

Gravely F. H., 1915, *Rec. Ind. Mus.*, XI, pp. 358-363, pl. XX, Lyropaeus biguttatus Westwood and some 'Trilobite Larvae', (references to literature).

Kleine R., 1928, *Ind. For. Rec.*, XIII, vi, pp. 221-268, Neue Indische Lycidae, nebst faunistischen Bemerkungen.

— 1930, *tit. cit.*, XIV, pp. 287-289, Three new species of Lycidae.

— 1933, *Catalogue of Indian Insects*. Part 21-Lycidae, pp. 52.

— 1933, *Ind. For. Rec.*, XVIII, ii, pp. 1-4, Entomological investigations on the spike disease of sandal, (5) Brenthidae and Lycidae.

— 1935, *tit. cit.*, Ent, I, No. 3, Neue Brenthiden und Lyciden aus Indien.

— 1937, *tit. cit.*, Ent., II, No. 10, Neue Brenthiden und Lyciden aus Indien.

Calochromus darjeelingensis, C. kaschmirensis and **C. tarsalis.** These species occur at high levels in the Himalayas and their larvae live and pupate in the rotten wood of logs and stumps of *Alnus nitida, Cedrus deodara, Juglans regia, Picea morinda, Quercus incana.*

Conderis signicollis, a widespread species, occurs as larva in the dead bark of *Ficus rumphii.*

Lycostomus madurensis and **L. praeustus** occur commonly on the flowers of *Santalum album* and are presumed to feed on nectar and pollen (Hart and Rangaswamy, 1926, *Ind. For.*).

Lyropaeus biguttatus in south India, has a trilobite larva (16 mm.) living free on the ground; it pupates in a sheltered cavity with the pupa hanging head downwards from the mid-dorsal fissure of the cast larval skin which remains unshrivelled in the position taken up by the larva before pupation. The larva and pupa are described by the Gravely, 1915.

Plateros imitator, throughout India, lives in dead wood of *Buchanania latifolia.*

LYCTIDAE see BOSTRYCHIDAE

LYMEXYLONIDAE

ALTHOUGH only a small number of *Lymexylonidae* are known from the Indian area the family is of much interest biologically and economically. The beetles are easily recognisable by the long slender bodies, short antennae and ample hind wings (and in some genera short flap-like elytra—a feature which appears also in a few genera of Cerambycidae). Rather specialised conditions are required for breeding, viz., dying top-broken trees or logs that remain green and sappy for long periods, but when these are available breeding is prolific. The beetles assemble in swarms at dusk, the action in flight resembling that of Mayflies. In their diet and wood-boring habits the larvae have features in common with some groups of Brenthidae. They feed on sap and moulds and not on wood-dust which is pushed out of the gallery from time to time

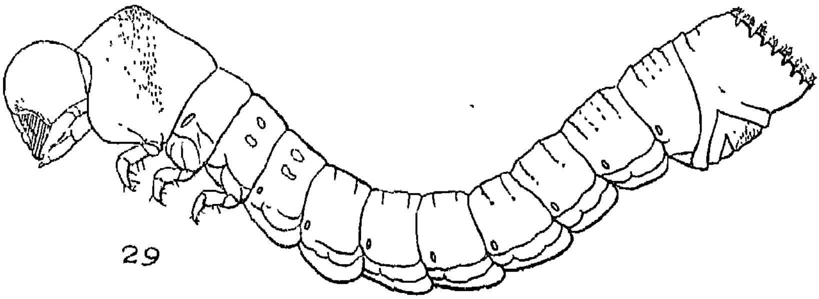

Fig. 96. Larva of Mellittoma albitarsis, natural size 10 mm., a borer of Bombax malabaricum.

as the gallery is lengthened and widened; for the purpose of cleaning the gallery the last abdominal segments of the larva are modified into a scraping or shovelling instrument.

Larvae of *Atractocerus* are elongate, slender, cylindrical forms with the prothorax swollen into a hood over the head, well developed 5-segmented legs and the 9th abdominal segment cylindrical and obliquely elevated, its apex truncate and carrying two anteriorly converging lines of asperities forming roughly the two sides of a triangle and more or less abundant smaller asperities within the triangular space.

Larvae of *Melittomma* [fig. 96] have the truncate extremity of the 9th abdominal segment circular and concave with a raised margin which is regularly crenulate except dorsally. This phragmatic structure recalls the posterior declivity of some males of *Diacavus* and *Crossotarsus* beetles (Platypodidae) and evidently has the same function of scraping and ejecting the refuse from the tunnel.

Wood which is attacked by Lymexylonidae is riddled with large perforations and tunnels and an attacked log or tree is marked by a heap of fine wood-dust fallen from the ejection-holes. The generation is annual with a restricted emergence-period in the dry hot weather preceeding the monsoon.

LITERATURE ON LYMEXYLONIDAE:

Gardner J. C. M., 1926, *Ind. For. Rec.*, Ent., XII, x, pp. 280-282, figs. 1-7.

— 1929, *tit. cit.*, XIV, iv, p. 111.

— 1937, *tit. cit.*, III, No. 6, pp. 128, 129, figs. 29-32 (Descriptions of larvae of Lymexylonidae).

Atractocerus blairi bores the wood of *Terminalia myriocarpa;* beetles emerge in August, September.

Atractocerus emarginatus bores the wood of *Artocarpus nobilis*, *Buchanania latifolia*, *Dipterocarpus turbinatus*, *D. zeylanicus*, *Shorea robusta*. Widely distributed within the west Oriental Region but not common. The testaceous brown beetle

is very variable in size; the eyes are contiguous; the elytra are minute rectangular flaps and the abdomen is very elongate.

The larva is slender, and nearly cylindrical, 45 mm. long, legs well developed, 5–segmented, prothorax swollen into a hood concealing the head from above, 9th abdominal segment cylindrical with the apex obliquely truncate and furnished with a cordate patch of transverse ridges. A technical description is given by Gardner, 1926, *Ind. For. Rec.*, XII, x, pp. 280–282, figs. 1–7. The larval tunnel is curved or sinuous for 6 or 8 inches from the surface of the sapwood towards the centre or opposite side of the log and lies in a plane horizontal to the axis of the log. It varies considerably in diameter according to the size and age of the larva but is cylindrical, i. e., of the same diameter from one end to the other. The wood-dust resulting from its excavation is ejected outside and a food-fungus grows on the walls which are stained black. The larva moves freely up and down its length and is able to turn in it. When a log is attacked by this species the infestation is usually abundant and the tunnels are crowded so that a tangential or radial plank of wood cut from the log is closely perforated with circular and oval holes. The life-cycle is annual and beetles emerge in March–May (mainly in April) and the emergence-period is well defined.

Atractocerus quercus bores the hard sound wood of *Quercus dilatata* and *Q. incana* in the Himalayas. The larva 25 mm. long, makes clean-cut cylindrical tunnels running radially for 2 or 3 inches from the surface of the sapwood; these vary in diameter with the age and size of the larva and are clean of wood-dust. The beetle is black, 11–24 mm. long, with elytra slightly longer than the prothorax; emergence in June.

Atractocerus reversus bores the wood of *Boswellia serrata*, and *Lannea grandis*. The beetle in appearance and habits is similar to *A. emarginatus*. The larval tunnels may reach a length of 10 inches. Emergence occurs in April, May. The larva is described by Gardner, 1929, *Ind. For. Rec.*, XIV, iv, p. 111.

Melittoma albitarsis bores the wood of *Bombax malabaricum making tunnels similar to those of Atractocerus emarginatus.* The beetle has the elytra elongate leaving part of the abdomen exposed. The larva, 10 mm. long, is cylindrical with the circular truncate extremity of the 9th abdominal segment with a raised margin, regularly crenulate except dorsally where it becomes a carina flanking a median lobe. (Gardner, 1937) [see fig. 96]. The life-cycle is annual and emergence occurs in May, June.

MALACHIIDAE see MELYRIDAE

MALACODERMIDAE see LAMPYRIDAE, LYCIDAE, MELOIDAE

MELANDRYIDAE

THE family of the MELANDRYIDAE is allied to the Tenebrionidae; its larvae bore in decaying wood or in fungi. Some species are reported to be technically injurious to wood of silver fir, spruce and larch in Europe and North America.

Dircaea vitalsi in wood of *Macaranga denticulata.*

Perakianus bicolor and **P. 4-costatus** in wood of *Terminalia tomentosa*, emerging in July, August.

Stenopalpus abdominalis in wood of *Quercus spicata*, emerging in February–April.

Talayra striata in wood of *Bombax malabaricum*, *Ficus glomerata*, *Garuga pinnata*, *Sterculia villosa.* There are two emergence-periods in April–July and September–December.

MELASIDAE see EUCNEMIDAE

MELOIDAE

MELOIDAE appears to be the correct family name to use for the Blister Beetles and their allies; Cantharidae and Telephoridae are used in some entomological textbooks. The beetles of most species are large, $\frac{1}{2}$ to $1\frac{1}{4}$ inches, and conspicuously coloured with red and black transverse bands, or with the elytra wholly green or black or bluish-grey, etc., and the vertical mobile head or pronotum of another colour; they congregate in large destructive swarms on foliage and flowers. The life-history is remarkable for the occurrence of hypermetamorphosis of the larva, i. e., there is an unusual variety of form in the successive larval instars.

Life-history: Eggs are laid by the female in very large numbers, often thousands, in holes in the soil where they hatch after 2 or 3 weeks. The first instar larva is an active, hard-skinned, campodeiform type *(triungulin)*, which is fitted to travel far and wait long until it finds its proper food—the eggs of Orthoptera and aculeate Hymenoptera; its life is therefore precarious and undoubtedly considerable mortality occurs in this stage. The triungulin of a species dependent on solitary bees attaches itself to the leg of a passing bee and is carried to the nest or cell of the bee, where it transfers at the time the bee's egg is laid and subsequently feeds parasitically on the egg and the store of honey or food provided for the hymenopterous larva. The triungulin of a species dependent on Orthoptera enters the egg-mass of a grasshopper and feeds on the contained eggs. In their subsequent instars the meloid larvae metamorphose into various types corresponding to the soft-bodied, cruciform and caraboid types; there is also a pseudo-pupal stage in some cases intervening before the last larval instars and the true pupa. The immature stages thus range from extreme activity to quiescence.

The life-cycles of Indian forms have not been studied in detail.

Species of *Lytta*, *Mylabris* and *Zonabris* pass their larval life in egg-masses of grasshoppers (Acridiidae) and their abundance is closely bound up with the fluctuation in the populations of their hosts.

Cantharidin: The Blister Beetles owe their name to the fact that a pharmaceutical product, cantharidin, is prepared from the dried insects, principally from the elytra of species of *Mylabris* and *Lytta*. Various preparations of these beetles are used for plasters and liniments in such ailments as pleurisy, neuritis and rheumatoid arthritis, whilst the tincture is administered internally for certain diseases; it is also used in cosmetics, hair oil, etc. Commercial supplies of the true Blister Beetle, *Lytta vesicatoria*, come mainly from southern Russia, Rumania and Spain (whence it is sometimes known as the Spanish Fly). Enquiries have from time to time been received as to the possibility of collecting *Mylabris* in the Punjab and Central India but an industry has not developed. Some time ago the Government Medical Stores obtained supplies of beetles from the neighbourhood of Gwalior but now the dried beetles and cantharidin preparations are imported at high prices.

Several species are pests of agricultural crops and occasionally in forests.

Cantharis rouxi and **C. tenuicollis**, 15–20 mm., are metallic green blister-beetles sometimes found in large swarms; the larvae feed on egg-masses of Acridiidae.

Epicauta hirticornis, a bluish-black beetle with a red head, occurs on flowers of Labiatae and on grasses in the Himalayas and is reported as a defoliator of *Quercus incana*. [fig. 4, No. 34 shows the beetle of *Epicauta ruficeps*].

Horia debyi is parasitic in the larval stage in the tunnels of the carpenter bee, *Xylocopa aestuans* (Apidae), feeding on the egg and the bee-bread stored for the use of the bee larva. The beetle yields cantharidin.

Lytta antennalis and **L. flavipennis**, with yellow elytra and a brilliant metallic green head and thorax, defoliate *Fraxinus excelsior* and other associates, e.g., *Lonicera alpigena*, *L. angustifolia*, *L. orientalis*, and *L. quinquelocularis*.

Mylabris chicorii, a red and black banded species, is abundant in north India during the rainy season.

Mylabris macilenta and **M. pustulata** are beetles (½ to 1 inch long) marked boldly with transverse bands of orange-red and black on the elytra, [fig. 4, No. 35], and are general feeders on flowers and young leaves particularly of Cucurbitaceae, Leguminoseae and Malvaceae. The beetles swarm annually when Hibiscus blossoms in the rains, but may be found in south India throughout the year. The larva feeds in egg-masses of grasshoppers (Acridiidae).

Mylabris phalerata, another red and black banded species, is a

general pest of garden flowers and fruit trees in the hills. It was once included officially in the British Pharmacopœia and used as an agent for making external applications in India. Species of *Mylabris* usually yield a larger amount of cantharidin than do those of *Lytta*. To be of commercial value Blister Beetles should contain 1.0 to 1.3 percent of cantharidin; they should be killed with a poison-gas or by heat, dried whole and packed with some napthalene dust to prevent growth of moulds and fermentation in the wet season.

Iyer and Guha (1931, *Journ. Ind. Inst. Sci.*, XIV A, iii, pp. 31–39) have shown that *M. pustulata* yields about 2.9 percent cantharidin as compared with a maximum yield of 1.9 percent from Chinese beetles and 1.2 percent from Spanish beetles. Puran Singh (1907, *Journ. Chem. Soc.*, A, ii, p. 994) had shown convincingly that cantharidin can be successfully extracted in India. With imported cantharidin at over Rs. 2 per gram, production from indigenous sources should be most profitable (see also Chopra, *Indigenous drugs of India*, pp. 193–195, Cantharides).

MELYRIDAE

A small malacoderm group, the MELYRIDAE consists almost entirely of carnivorous species. The agile campodeiform larvae roam about on the ground, on the bark of trees climbing the trunk and branches and also penetrating in the tunnels of wood-borers especially Cerambycidae. They feed on the larvae of other beetles and of moths, and on small worms and molluscs. In appearance the beetles might be thought to resemble some Cleridae to which they are allied. Descriptions of some Indian larvae are given by Gardner (1929, 1931).

Carphurus almorensis visits the galleries of borers such as Cerambycidae and Mordellidae in slender stems of *Combretum decandrum* and *Cryptolepis buchanani* and other trees The *Carphurus* larva, 10 mm. long, is predaceous on the borer larvae; it is described by Gardner, 1931, *Ind. For Rec.*, XVI, iv, pp. 97, 99, figs. 16–20.

Idgia flavibuccis is predaceous as larva and beetle on caterpillars and their pupae freshly formed (*Hypsipyla robusta*, Pyralidae), climbing trees in search of them. The larva occurs in April–June and lives for several weeks; the pupal period in May, June lasts one week. A description of the larva, which is orange or pinkish with black markings, about 15 mm. long, is given by Gardner, 1929, *Ind. For. Rec*, XIV, iv, p. 110, fig. 16.

Idgia melanura feeds on insect remains (Vespidae). The larva lives for more than 2 months in the rainy season and more than 3 months in the cold season. The pupal period is about one week. There are possibly 3 generations a year in north India. The orange-yellow, black marked larva, 17 mm. long, is described in 1929, *lit cit.*, pp. 108–110, figs. 13–18.

MORDELLIDAE

SOME of the species in this small heteromerous family of MORDELLIDAE are borers of fungi and others are borers of decaying or dry wood *(Glipa)* and others of living herbaceous stems and grasses *(Mordellistena)*. The beetles often visit flowers (e.g., *Anaspis)*.

The life-cycle of the wood-boring species is ordinarily annual. Species attacking herbaceous stems of *Artemisia*, *Cannabis*, *Datura*, *Valeriana*, etc., oviposit on the living stem at the angle of the leaf-petiole and the elongate curved larva bores in the pith; the stem eventually withers or breaks off.

Calcyina gardneri in wood of *Terminalia tomentosa* emerging in May–July.

Glipa stenalioides in wood of *Canarium euphyllum* and an unidentified woody liane in the Andamans, emerging in April, May.

Glipa tricolor in wood of *Acrocarpus fraxinifolius*, *Crataeva unilocularis*, *Elaeocarpus varuna*, *Hymenodictyon excelsum*, *Litsaea polyantha*, *Sapium eugeniaefolium*, *Sterculia colorata*. Emergence takes place from May to September and the life-cycle is annual or longer.

Mordella aculeata in rotten stems of *Jatropha curcas*.

Mordellistena cuneigera in wood of *Girardinia heterophylla*. **M. daturae** in wood of *Shorea robusta* and an unidentified liane, emerging in April–June. **M. gardneri** in wood and dry sticks of *Alnus nepalensis*, *Artemisia vulgaris*, and *Cannabis sativa*, emerging in May–July.

MYCETOPHAGIDAE

MINUTE clavicorn beetles living in decaying bark and wood, some of which feed on fungus or mould: hence the family name MYCETOPHAGIDAE. One species, **Berginus maindroni**, India and Ceylon, is recorded by Imms and Chatterjee, 1915, *Ind. For. Mem.*, III, i, pp. 36, 37, pl. vii, fig. 29, as a predator of the lac insect. Its association with lac is, however, very infrequent and it is not predaceous. **Typhaea stercorea**, a cosmopolitan beetle, is another species sometimes found in lac sticks.

MYLABRIDAE see BRUCHIDAE
NIPONIIDAE see HISTERIDAE

NITIDULIDAE

NITIDULIDAE are a family of clavicorn beetles living in diverse environments and having a varied diet. They are for the most part scavengers feeding on fermenting or decaying vegetable matter, particularly exuding sap, souring fruit and withering flowers, decomposing bark and sapwood, fungi and moulds as well as fresh pollen; some genera feed on decomposed or putrified

flesh, carcases and bones; some are definitely predaceous on living insects particularly bark-borers and the associated corticolous insects, while at the same time able to subsist on bark and vegetable debris. The last group includes important enemies of the beetles and larvae of bark-boring Scolytidae.

The life-histories of no Indian forest species has been studied in detail but very many genera have been bred out of caged logs and the beetles are always abundant under bored or loosened bark. The catalogue lists 230 species which are only a small sample of the total fauna.

LITERATURE ON NITIDULIDAE:

Chatterjee, S. N., 1924, *Catalogue of Indian Insects*, Part 5-Nitidulidae.

Amphicrossus opacus is an example of species feeding on sappy exudations from the bark of trees.

Carpophilus dimidiatus, C. hemipterus, etc., beetles 3-4 mm. long, breeding in fermenting plant-tissues, dried fruits and similar substances.

Cybocephalus semiflavus is an example for a type predaceous on Coccidae.

Epuraea apicalis represents a type predaceous on Scolytidae.

Lasiodactylus pictus and other species breeding in over-ripe fruits.

OEDEMERIDAE

THE heteromerous or mordelloid family, the OEDEMERIDAE, is composed almost entirely of borers of dead or decayed wood and particularly of wet rot conditions, of driftwood and the timber used in bridges, wharves and mines. The larva has an elongate, fairly cylindrical, separately segmented, soft skinned body, rather conspicuously setose, with long legs. The tunnel is of circular cross-section, packed loosely with frass and resembles somewhat that of Siricidae. It is carried deeply and irregularly into the wood and returns near to the surface before the larva prepares to pupate. The life-cycle is annual or extended for a second year.

LITERATURE ON OEDEMERIDAE:

Gardner, 1929, *Ind. For. Rec.*, XIV, iv, pp. 127-129, figs. 51-55.
— 1931, *tit. cit.*, XVI, iv, pp. 105-106, figs. 55-57.

Asclera indica. Inhabits dead wood in populous colonies which mature in April with a short well-defined emergence-period after a life-cycle of one year which may be prolonged for another twelve months. The larva resembles that of *Falsosessinia* (Gardner, 1931, p. 16, fig. 54).

Falsosessinia sculpticollis is a widely distributed Oriental species boring rotting logs. The larva, 35 mm., is elongate, each segment more or less cylindrical, soft, rather bristly and is described by Gardner, 1929, pp. 127-129, figs. 51-55.

Oncomera bomfordi bores the dead roots of *Girardinia heterophylla*.

Xanthochroa himalaica bores the wood of *Casearia glomerata*. The larva and pupa are described by Gardner, 1931, pp. 105–106, figs. 55–57.

OSTOMIDAE see TROGOSITIDAE

PASSALIDAE

BEETLES of this small lamellicorn family PASSALIDAE are of flattened subparallel form, generally black, shining and longitudinally striate; the length varies from 10–55 mm. The larvae [fig. 97] are fleshy, elongate and more or less hairy, but less strongly curved than Lucanidae or Scarabaeidae; the hypopharyngeal sclerome is much less strong and solid than in allied families and the molar apparatus of the larva is thus not very suitable for crushing up the wood in which it lives; the first 2 pairs of legs are well developed but the posterior leg is a small stump bearing a few teeth and it can be rubbed on a finely striated patch on the basal segment of the middle leg so as to produce a shrill note (stridulation). The beetle also stridulates by rubbing rough patches on the dorsal surface of the abdomen against similar areas on the lower surface of the wings.

Life-history: The beetles excavate chambers inside the wood (most species) or beneath the bark (some flattened species of *Leptaulax)* of rotting logs of fallen trees or stumps. Some species occur in quite hard wood that needs an axe to cut it—others inhabit wood so soft and rotten that it is easily broken up with the fingers; many species prefer moist or fully saturated wood—others do not leave their tunnels until the wood has become dry. Eggs are laid in the cavity in a loose cluster usually in small numbers, 5–10 for one colony; the egg of *Basilianus* is black, finely reticulate and stoutly oval. The larvae hatch out and live in the free space of the beetles' chamber; they grow to a length of 30–50 mm. The parent beetles remain with the eggs until they hatch and with the larvae during their growth and, according to some entomologists, protect them and feed them, excavating the wood and crushing it or partly masticating it, for the nourishment of the larvae (progressive provisioning). The weak molar apparatus of those species of larvae known to live gregariously with their parents appears to be correlated with this habit. Adult and larva are recorded to communicate with one another by stridulation. Wheeler, 1928, classes the Passalidae as subsocial insects. Heymons, 1929, considers there is no evidence for a truly subsocial habit; the parents do not feed the larvae which can hatch from the egg and be reared successfully in the absence of beetles. The stridulation of the larvae is a symptom of excitement resulting from a stimulus and is not connected with feeding-habits.

Gravely, 1914, notes that adults of nearly all species live in decaying wood in pairs with their young; but whereas in certain

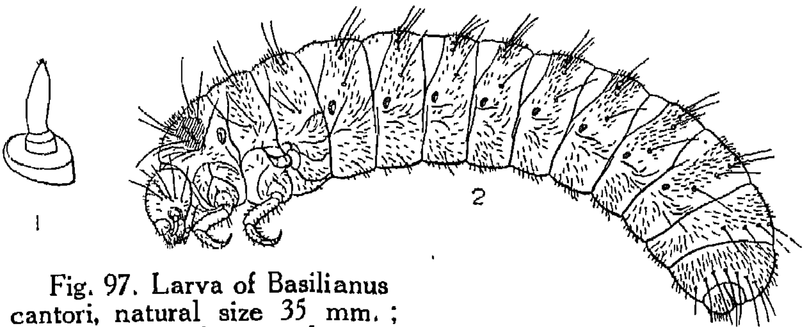

Fig. 97. Larva of Basilianus cantori, natural size 35 mm. ; the antenna is shown enlarged.

species large numbers of such families are commonly found in a single log so closely associated with one another that it is often impossible to separate out the individuals belonging to any single pair, in other species each family forms an isolated group. The 5 dominant species, *Aceraius grandis*, *Basilianus cantori*, *B. stoliczkae*, *Episphenus comptoni* and *Tiberioides kuwerti* are all gregarious.

The length of the life-cycle has not been determined. Beetles live for several months; reproduction is retarded or ceases during the dry cold weather.

Economic importance: In certain regions, the forests of the Himalayas from Jaunsar eastwards, and the south Indian hills and in the less moist tropical forests the Passalidae are factors in the disintegration of fallen timber but they are not very numerous and they are exterminated where they come into competition with termites.

LITERATURE ON PASSALIDAE:

Arrow G. J., 1910, *Fauna Brit. Ind.*, Col. Lamellicornia. Introduction, pp. 1-23, fig. 7.

Gardner J. C. M., 1935, *Ind. For. Rec.*, Ent., I, No. 1, pp. 1-6, figs. 1-5, 77, 78, Immature stages of Indian Coleoptera (16), Scarabaeoidea.

Gravely F. H., 1914, *Journ. As. Soc. Bengal*, X, pp. 201-209, The evolution and distribution of certain Indo-Australian Passalidae.

— 1914, *Mem. Ind. Mus.*, III, pp. 177-353, pls. xi-xiii, An account of the Oriental Passalidae based primarily on the collection in the Indian Museum.

— 1915, *Rec. Ind. Mus.*, XI, pp. 495-497, pls. xxii-xxv, Notes on the habits of Indian insects, myriapods and arachnids.

— 1916, *Rec. Ind. Mus.*, XII, pp. 137-175, pls. xx-xxii, Some lignicolous beetle larvae from India and Borneo.

— 1918, *Mem. Ind. Mus.*, VII, pp. 1-144, figs. xiii, pl. i, A contribution towards the revision of the Passalidae of the world.

Aceraius grandis breeds in rotting but fairly tough wood of *Anthocephalus cadamba* and *Castanopsis tribuloides*. The larva, 50 mm. long, is described by Gardner, 1935, *Ind. For. Rec.*, Ent. I, No. 1, p. 5, fig. 5 and Gravely, 1916, *Rec. Ind. Mus.*, XII, p. 142.

Basilianus cantori breeds in the wood of *Betula utilis, B. cylindrostachys, Carpinus viminea, Castanopsis tribuloides, Machilus odoratissima, Pinus longifolia, Quercus incana, Q. dilatata, Symplocos theaefolia* in the Himalayas. The wood is usually very rotten and wet. A colony of 4 to 6 larvae occurs with the pair of beetles. The egg is black, stoutly ovate, 3·5 mm. long. The larva, 35 mm., [fig. 97] is described 1935, *tit. cit.*, p. 6, figs. 1-4, 77, and Gravely, 1916, *Rec. Ind. Mus.*, XII, p. 141.

Basilianus neelgherriensis and **B. stoliczkae** in south India are other species inhabiting quite rotten wood. The larva of the latter is described *tit. cit.*, p. 6. *E. neelgherriensis* is apparently not gregarious and beetles occur also under stones and at light. The larva, 35 mm., is described by Gravely, 1916, *Ind. For. Rec.*, XII, p. 141.

Episphenus comptoni breeds gregariously in *Acacia melanoxylon, Calophyllum walkeri, Michelia nilagirica, Rhododendron arboreum, Semecarpus thwaitesii* in south India and Ceylon.

E. moorei breeds in *Mangifera zeylanica*.

Leptaulax bicolor inhabits the wood and bark of logs of *Sterculia villosa*. It does not burrow deeply; beetles, larvae and pupae occur close under the bark. The larva, 30 mm., is described by Gardner, 1935, *tit. cit.*, p. 5, fig. 78, and Gravely, 1916, *Rec. Ind. Mus.*, XII, pp. 139, 140, 144.

Leptaulax darjeelingi occurs in the wood of *Albizzia stipulata* and *Bombax malabaricum*.

Leptaulax dentatus occurs gregariously in wood of logs of *Bombax malabaricum, Ficus elastica* and *Shorea robusta* in north India; the species extends to Malaya. It prefers very rotten wood.

Leptaulax evidens breeds in rotting wood of *Anthocephalus cadamba*.

Pleurarius brachyphyllus, of south India, makes deep galleries in wood that is often quite hard and the larvae are commonly widely separated from the adults. The larva, 50 mm., is described by Gravely, 1916, *Rec. Ind. Mus.*, XII, p. 140, pl. XX.

Tiberioides kuwerti feeds in rotten wood of *Juglans regia*.

PAUSSIDAE

So far as is known the 60 odd species of the small family PAUSSIDAE are entirely myrmecophilous. The small red, brown or black beetles, which commonly come to light, are remarkable for their bizarre specialized antennae and hair-tufted secretory spots. The host-ant species are known in many cases, e.g., **Merismoderes bensoni** with *Prenolepis longipes*, **Paussus desneuxi** with *Tetramorium tortuosum*, **P. escherichi** with *Pheidole indica*, **P. cardoni** and **P. jerdani** with *Pheidole latinoda*, **Platyrhopalus angustus** with *Solenopsis geminata*; but practically nothing has been observed on the early stages of Indian Paussidae.

LITERATURE ON PAUSSIDAE :
Fowler W. W., 1912, *Faun. Brit. Ind.*, Col., Paussidae, pp. 444-500, figs. 200-220.
Ribeiro S., 1930, *Rec. Ind. Mus.*, XXXII, pp. 223-246, figs. 18, Notes on some Indian Paussidae with the description of a new species.

PLATYPODIDAE

PINHOLE Borers, Shothole Borers and Ambrosia Beetles are the names shared by the members of the family PLATYPODIDAE with certain groups of the Scolytidae having similar habits. Living exclusively in the wood of trees the Platypodidae are characteristic elements in the beetle fauna of tropical mixed forests throughout the world; their geological history shows that they evolved in a similar environment early in the differentiation of the rhynchophorous stock. In the Ceylon-India-Malaya region many new species have been discovered in recent years by the forest entomologists and by F. G. Browne and M. L. Webber of the Malayan Forest Service; about 100 species are known from Malaya and 150 from the remainder of the region; naming has been done by Beeson, Sampson and Schedl. The classification of the family is not yet satisfactorily constructed and most of the species have been placed in two unwieldy genera, *Crossotarsus* and *Platypus.* Several taxonomists place the Platypodidae together with the Scolytidae at the peak of evolution of the Coleoptera (see p. 39) and *Diapus* as the youngest phylogenetic product; at any rate these beetles appear to have reached an almost ideal specialisation for life as wood-borers.

Beetle: The range in size is 2-12 mm. [figs. 98, 101]. While the cylindrical shape of the beetle is fairly uniform in all species—and, moreover, is the most efficient body-form for an inhabitant of open tunnels—there is a fantastic compensatory variation in terminal parts, i. e., the front of the head, mouth-parts, the elytral declivity and the last abdominal sternites. These devices have evolved in response to such vital activities as the excavation of the tunnel, the transport of eggs, the scraping, shovelling and ejecting of refuse, the transfer of ambrosia-fungus, the defence of the entrance-hole, etc.; division of labour between the sexes is accompanied by contrasted secondary sexual characters.

Larva: The mature larva [fig. 101; fig. 98, No. 3; fig. 99, No. 3] is soft-skinned, nearly straight, cylindrical and somewhat more muscular at the prothorax and near the middle of the body; it fits closely into its tunnel touching the whole circumference when a body-segment is expanded; being legless it crawls by alternating expansion and contraction of the segments in a progressive ripple. The young larva [fig. 98, No. 3] is ovoid in outline, too small to span the width of the tunnel, and forced to crawl by adhesion to one side of the wall. Larvae feed entirely on the ambrosia-fungus growing on the walls of the tunnel and

do not eat wood. Correlated with this diet is the peculiar structure of the clypeus, labrum and epipharynx which form a large trapezoidal organ with the epipharyngeal surface strongly protuberant and a finely ridged area that is opposed to a somewhat similar area on the mandible; the lymexylonid larva which feeds on an ambrosia-fungus also has a coadaptation of epipharynx and mandible.

Life-history

The life-history is very uniform throughout the family; this generalised account applies to most of the species.

Swarming: The life cycle commences with the flight of the beetles from the timber in which they were bred to new breeding-material, i.e., susceptible living trees or newly felled and fallen logs. It is probable that the adult life spent in the open is very short—a few hours to 1 or 2 days—and they soon bore into the bark of another tree to found a new home. During this period the fructifications of the ambrosia-fungus are transported by means of special devices such as tufts or baskets of long bristles, secretory pores, pits, etc.; some structures like mandibular processes and brushes of frontal bristles are dispensed with after the flight, either shed voluntarily as a termite sheds its wings, or broken off during the excavation of the entrance-hole.

Gallery-system: The entrance-tunnel is usually drilled by the female; in some species of *Crossotarsus* and *Diapus* the male does the preliminary work and the female takes over the excavation shortly after. From the bark an entrance-tunnel is sunk radially into the sapwood and then the main tunnel turns to left or right. In large logs this tunnel is continued parallel to the heartwood and the outer circumference [fig. 99, No. 1; figs. 100, 101]; in small branch or stem-wood without definite heartwood the full depth of several inches is penetrated in a sinuous or spiral course [fig. 99, No. 4]. From the main gallery secondary galleries branch off and run for shorter or greater distances. In very elaborate systems there is much linkage by cross-tunnels or even vertical shafts. The plane of this gallery-system is usually horizontal, i. e., at right angles to the axis of the bole but it may become oblique with the grain or descend and ascend far from the average level *(Platypus)*. In one group, *Crossotarsus*, the branch-galleries are not in the same plane as the main gallery, but are at right angles to it, i.e., vertical or axial; these vertical branches divide into adjacent tertiary branches producing a dendritic or candelabra-like ramification. [fig. 98, Nos. 2, 4, 5].

Oviposition: The first batch of eggs is laid simply at the end of the tunnel as soon as it is deep enough and later transferred to a short branch-tunnel out of the way while the excavation and removal of the debris of the main tunnel proceeds. The female uses her antennae and forehead in moving the eggs. One

individual lays some scores of eggs over a period of several weeks; ordinarily all mature to the pupal stage as platypodid larvae are well protected against parasites and predators.

F o o d : The parent beetles, and probably the larvae, take sap exudates from the broken wood-tissues as part of their food. An ambrosia-fungus, *Monilia* or *Penicillium* grows on the walls of the tunnels spreading its hyphae into the wood-tissues and staining them black. Where it can grow freely the mycelium forms dense cushions and hummocks that eventually fill the bore entirely or block it with fruiting bodies; but it is continually browsed down by the beetles and larvae, and passages are kept open. Very little is known of what takes place inside the dark moist depths of the platypodid underworld: there must be a systematic or automatic cultivation of the crops of ambrosia in conformity with the growth of the population of the colony: there must be an organised extension of galleries and a regulated traffic keeping open thoroughfares for the larvae and for the removal of wood-dust and faecal matter—the spoil of the excavations. The social life of a persistent colony is further complicated by the addition of the second generation beetles and by intrusion and intermingling of neighbouring colonies. It is supposed that the control and protection of a colony and its food-supply depend entirely on the parent founders.

W o r k o f t h e m a l e : One of the main functions of the male is to collect and remove (a) the wood-dust produced by the female who is drilling at the end of the gallery, and (b) the faecal pellets of the larvae; these waste products are pushed to the mouth of the entrance-tunnel and thrown out. During rapid extension of the tunnels the wood-dust is pushed out in coherent cylinders or strings which persist for an inch or two before breaking; during the larval feeding-period the refuse is almost wholly faecal pellets thrown out as a non-coherent dust. The hind end of the male—the apices of the elytra, abdominal sternites, hind coxae and femora—are shaped into a variety of ingenious structures to act as scrapers, rakes and scoops. Another service of the male is defence of the entrance, which is blocked up either by a solid plug or a perforated diaphragm of mixed debris, or by a tube of wax secreted by the male elytra, or simply by means of the hind end of the body.

P u p a l c h a m b e r : The pupal chamber is a cell, as long as the larva, constructed vertical to the branch-gallery, i.e., in the run of the long wood vessels. In *Platypus* the chambers are arranged in rows above and below the branch-gallery and a short distance apart so as to form an open palisade [fig. 99, No. 2]; in *Diacavus* and *Diapus* they are nearly contiguous in groups alternating with their opposite numbers and forming a closed fence [fig. 100]; in *Crossotarsus* each chamber is in continuation of and

terminates a vertical branch-gallery [fig. 98, No. 2]. The pupal cell is excavated by the larva and this is the only boring done by the larva throughout its life.

Duration of life-cycle: The life-cycle from the time of boring in by a pair until the offspring begin to swarm may be 5 or 6 weeks (*Crossotarsus*); 10-11 weeks for *Diacavus furtivus;* 2 generations a year occur in *Platypus biformis* in the Himalayas; an annual generation is recorded for *Diapus pusillimus* in the subtropics (J. H. Smith). The period of occupation of a log by colonies of pinhole borers is determined by the rate of seasoning or desiccation. When the moisture-content has fallen to about 50 percent the wood is vacated by the beetles. The total emergence-period of the occupation may last for 6 months and all broods escape through the original entrance-tunnel of their parents or that of an adjacent colony if linkage has connected them. New exit-tunnels are not made.

Economic importance.

A few species attack standing living trees (e.g., *Crossotarsus impar)* but without killing them; others attack living trees at wounds and tunnels in the dead bark and cambium but fail to penetrate the living tissues capable of exuding gum, resin or latex; some are able to establish themselves in charred logs (of green timber) entering through the cracks in the charcoal; others make exploratory cavities in sawn timber while it is moist but abandon them when it is dried. The prevailing habit is to bore into dead or dying trees through the intact bark. The timber is spoiled by the disclosure of pinholes and streaks on sawn faces owing to the trans-section of the galleries on all aspects; the pinholes are often surrounded by a zone of discolouration. Structurally the lumber is scarcely at all weakened by the presence of pinholes—unless they are very abundant—in which case the wood is likely to be fungus-rotted as well.

Newly felled boles, logs and branches are attacked within a few hours of felling and they continue to be liable to further attacks so long as they remain moist enough. Dry or seasoned timber is immune. Most species of Platypodidae are polyphagous or at least oligophagous in allied genera or families of plants; *Crossotarsus saundersi* attacks over 100 species of trees; monophagous species are uncommon, e.g., *Diacavus furtivus* in *Shorea robusta*. Platypodids, like other ambrosia-beetles of the Scolytidae, are most injurious in numbers of species and in abundance of individuals in the tropics, particularly in mixed evergreen and rain forests. Extensive logging operations in evergreen forests in the Andamans, West Coast, Burma or Malaya inevitably accumulate vast quantities of felling-refuse in which pinhole borers multiply to incredible abundance. White clothes may be obscured by

swarms of beetles that recall plagues of flies in Iraq or of mosquitoes in the tundras.

Species of *Crossotarsus*, *Diapus* and *Platypus* occur at 9,000–10,000 feet in the Himalayas.

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— 1939, *tit. cit.*, XVIII, pp. 327-364, 14 figs., Malaysian Scolytidae and Platypodidae IV.

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The genus **Crossotarsus** is difficult to separate from the genus *Platypus* on morphological characters of the adult but the larva is characterised by its spiracles and caudal extremity (Gardner 1932, p. 3), and the gallery-system has pupal cells at the ends of groups of vertical branch-galleries [fig. 98, Nos. 2, 4, 5].

Crossotarsus amoorae, 5 mm., in *Amoora spectabilis* in Assam.

C. andamanus, 5·5–5·9 mm., in *Diospyros oocarpus*, *Dipterocarpus turbinatus*, *Myristica andamanica*, *Pterocarpus dalbergioides*, *Sageraea elliptica*, *Terminalia manii*, *T. procera*, is known only in the Andamans; emergence-period of an infestation extends over 4 months. The horizontal main gallery sometimes turns at right angles upwards for a few inches and then turns again into a new horizontal plane; from each of these sections vertical branch-galleries are run out.

C. (Carchesiopygus) assamensis, 5·9–6·1 mm., in *Vatica lanceaefolia*.

C. bonvouloiri, 8·5–9·5 mm. [fig. 4, No. 49, male beetle], in *Cryptocarya wightiana*, *Dalbergia cultrata*, *Dysoxylum binectariferum*, *Engelhardtia spicata*, *Mallotus albus*, *Mesua ferrea*, *Pterospermum acerifolium*, *Sapium eugeniaefolium*, *S. sebiferum*, *Shorea robusta*, *Vatica lanceaefolia*, *Xylia dolabriformis*. Bengal to Thailand. The very large black-stained tunnels ruin

the timber, running right through a log on the cross-section and for 2 or 3 inches vertically above and below the cross-tunnel [fig. 98, No. 4]. Eggs are picked up by the female with her specially elaborated antennae and are carried in specially shaped concavities in her forehead.

C. brownei, 3–9 mm., in *Elateriospermum tapos* and *Pithecolobium* sp. in Malaya.

C. cincinnatus, 8·0 mm., in *Adinobotrys atropurpureus*, *Afzelia bakeri*, *Buchanania sessilifolia*, *Diplospora* sp., *Elateriospermum tapos*, *Endospermum malaccense*, *Mesua ferrea*, *Parkia speciosa*, *Sterculia macrophylla*, *Xanthophyllum* sp. in Malaya. The bore of the gallery is about 2·3 mm. and is on the same pattern as in *bonvouloiri*. Eggs are carried by the female in the front of the head. Larvae mature in 25 days and swarming occurs after 6 or 7 weeks. (Browne, 1935).

C. cinnamomi, 6–7 mm., in *Cinnamomum cecidodaphne* and *Ilex dipyrena*. The branch-tunnels run vertically for 4 inches from the main tunnel. Emergence extends from October to April in Assam, Bengal.

C. comatus, 9·0 mm., in *Afzelia bakeri*, *Grewia* sp., *Koompassia excelsa*, *Parkia speciosa*, *Sterculia macrophylla* in Malaya. (Browne, 1935).

C. coniferae, 4·5 mm., in *Abies webbiana*, *Cedrus deodara* and *Picea morinda* in the Himalayas.

C. emarginatus, 3·7 mm., in *Albizzia* sp., *Coccoceras muticum* and *Shorea bentongensis* in Malaya.

C. emorsus, 4·9–5·2 mm., in *Bauhinia malabarica*, *Careya arborea*, *Sterculia ornata*, *Tectona grandis*, *Xylia dolabriformis* in Burma.

C. fairmairei, 6 mm., in *Abies pindrow*, *Acer caesium*, *Cedrus deodara*, *Juglans regia*, *Picea morinda*, *Pinus excelsa*, *Prunus padus*, *Quercus dilatata*, *Q. incana*, *Q. semicarpifolia*, a high-level Himalayan species.

C. fractus, 4–4·2 mm., in *Afzelia bakeri*, *Albizzia odoratissima*, *Bassia butyracea*, *Bauhinia malabarica*, *Isonandra polyantha*, *Lannea grandis*, *Melanorrhoea usitata*, *Protium serratum*, *Styrax benzoin*, *Swietenia macrophylla*, occurs from Assam to the Philippines.

Crossotarsus impar. The beetle, 10 mm., bores in the following species of *Shorea: acuminata*, *curtisii*, *dasyphylla*, *eximia*, *lepidota*, *leprosula*, *macroptera*, *parvifolia*, *paucifolia*, *platycarpa*, *rugosa*, *singkawang* and *teysmannia* in Malaya.

This species is one of the most important insect pests of Malayan forests; it attacks nearly all species of *Shorea* of the red meranti group and unlike the majority of *Crossotarsus* confines its attack to living trees. The different species of *Shorea* vary considerably in their susceptibility to damage; 6 species are graded as susceptible or very susceptible, and the rest as resistant or fairly resistant. Intensity of attack varies considerably with

locality, and low-lying land subject to high rainfall is the most heavily infested. The incidence of damage is greatest near the base of a tree and decreases steadily with increase in bole-height: planks sawn from a base log may show 3 to 4 holes per square foot of face. The diameter of the bole or tunnel is 2·5 mm. After penetrating the sapwood in a more or less radial direction, it encircles the stem, leading down in a gradual spiral to near the centre of the tree; there are usually 1 or 2 shorter branch-galleries also strongly curved and these have shorter secondary branches. The pupal chambers are vertical, arranged in a 'ladder' sequence as in *Platypus* (to which genus *impar* should probably be transferred).

Browne F. G., 1936, *Malayan For.*, v, pp. 125, 126, fig. 7, Biological notes on Malayan ambrosia beetles.

— 1936, *Imp For. Inst.*, Paper No. 3, On the meranti shothole borer.

C. latelunatus, 4 mm., in *Dipterocarpus pilosus*, *Ehretia acuminata*, *Meliosma simplicifolia* in Assam.

C. lobacanthurus in *Quercus incana*.

C. minax, 6–6·5 mm., in *Anacardium occidentale*, *Bombax malabaricum*, *Buchanania latifolia*, *Butea frondosa*, *Calycopterus floribunda*, *Diospyros ovalifolia*, *Eugenia* sp., *Gluta travancorica*, *Hevea brasiliensis*, *Lagerstroemia lanceolata*, *Lannea grandis*, *Mangifera indica*, *Mesua ferrea*, *Pterocarpus marsupium*, *Semecarpus gardneri*, *Spondias mangifera*, *Swietenia macrophylla*, *Tectona grandis*, *Terminalia arjuna*, *T. belerica*, *T. paniculata*, *T. tomentosa*, *Theobroma cacao*, *Warmia triquetra*, *Xylia dolabriformis*, occurs in Ceylon and south India. The main tunnel runs horizontally right across a log of 1 foot diameter; the branch-tunnels run up vertically for about 2 to 4 inches. Emergence may continue for 5 months, November–March. The larva, 8·5 mm., is figured by Gardner, 1932, *Ind. For. Rec.*, XVII, iii, pp. 4, 5, figs. 1–7.

C. mussooriensis, 4 mm., in *Cedrela serrata*. **C. nicobaricus**, 3·6–3·8 mm., in *Anacardium occidentale*, *Lagerstroemia hypoleuca*. **C. nilgiricus**, 3·9–4·3 mm., in *Butea frondosa*, *Poinciana elata* in south India. **C. perceptus**, 5·2 mm., in *Engelhardtia spicata*. **C. psilacanthurus**, 5·2–5·4 mm., in *Castanopsis ? tribuloides* in Bengal. **C. puerulus**, 2·5 mm., *Elateriospermum tapos*, *Xylopia cordata* in Malaya. **C. quadricaudatus**, 6·7 mm., in *Palaquim ellipticum* in south India. **C. quadriporus**, 3·6–4·2 mm., in *Quercus lamellosa*, *Q. lineata*.

Crossotarsus saundersi

Widely distributed throughout the Oriental Region to the Australasian and African Regions; in India it is common in the districts of moderate rainfall but absent from the dry zone. The food-plants in India are: *Acrocarpus fraxinifolius*, *Adina cordifolia*, *Albizzia lebbek*, *A. lucida*, *A. odoratissima*, *A. procera*, *Alstonia scholaris*, *Amoora rohituka*, *Anacardium occidentale*,

Anogeissus acuminata, *Bassia butyracea*, *Bauhinia malabarica*, *Bombax malabaricum*, *B. insigne*, *Buchanania latifolia*, *Butea frondosa*, *Calophyllum spectabile*, *Canarium euphyllum*, *Cassia fistula*, *C. siamea*, *Castanopsis tribuloides*, *Casuarina equisetifolia*, *Cedrela odorata*, *Cynometra ramiflora*, *Dalbergia latifolia*, *D. sissoo*, *Diospyros oocarpa*, *Dipterocarpus macrocarpus*, *D. turbinatus*, *Doona zeylanica*, *Ehretia acuminata*, *Engelhardtia spicata*, *Eugenia jambolana*, *E. operculata*, *Ficus glomerata*, *F. tjakela*, *F. religiosa*, *Garuga pinnata*, *Heritiera fomes*, *H. littoralis*, *Lagerstroemia hypoleuca*, *L. parviflora*, *Lannea grandis*, *Machilus odoratissima*, *Mallotus alba*, *M. philippinensis*, *Mangifera indica*, *Melia azedarach*, *Meliosma simplicifolia*, *Millettia pendula*, *Mimusops littoralis*, *Murraya koenigi*, *Myristica andamanica*, *Nyssa sessiliflora*, *Parishia insignis*, *Phyllanthus emblica*, *Polyaltha simiarum*, *Poinciania elata*, *Protium serratum*, *Pterocarpus dalbergioides*, *P. indicus*, *P. marsupium*, *Randia uliginosa*, *Sageraea elliptica*, *Sapium eugeniaefolium*, *Semecarpus anacardium*, *Shorea robusta*, *Stereospermum chelenoides*, *Swietenia macrophylla*, *Tectona grandis*, *Terminalia belerica*, *T. mannii*, *T. paniculata*, *T. tomentosa*, *Tetrameles nudiflora*, *Vanguera spinosa*, *Vatica lanceaefolia*, *Xanthophyllum glaucum*, *Xylia dolabriformis*, *Zizyphus xylopyra*.

The subspecies **saundersi submontanus** Bees. occurs in the sub-Himalayan region of the United Provinces and is not known from south of the Ganges; it is slightly larger than the typical form, 4·1-4·4 mm.; its foodplants are included in the above list and are recorded separately by Beeson, 1937, p. 73.

The following additional species are food-plants in Malaya: *Adinobotrys atropurpureus*, *Afzelia bakeri*, *Balanocarpus heimii*, *Endospermum malaccense*, *Garcinia* sp., *Hevea* sp., *Koompassia excelsa*, *Parkia speciosa*, *Pithecolobium confertum*, *P. lobatum*, *Xanthophyllum* sp., *Xerospermum* sp.

Including the trees of other regions well over 100 foodplants are known for *C. saundersi*.

Life-history: The beetle [fig. 4, No. 46] is chestnut-brown, cylindrical, under 4 mm. long, with the apical corners of the elytra produced downwards into short projections. The larva is white, cylindrical, legless, 5 mm. long, (described by Gardner, 1932, *Ind. For. Rec.*, XVII, iii, p. 5, fig. 10).

The beetle bores into dying or newly felled trees and constructs an entrance-tunnel running radially towards the heart-wood and then turning to run parallel to the circumference. From the main tunnel vertical tunnels run upwards and downwards for 2 or 3 inches, and each divides at its end into 3 or 4 short vertical branches (similar to the system of *C. squamulatus*, fig. 98, No. 2). The tunnels are kept clear of wood-dust which is ejected in cylindrical lengths by the male beetle; an ambrosia-fungus grows and fruits on the walls which are eventually stained black.

Oviposition starts within 3 or 4 days of boring into the wood; eggs are laid free in the main tunnel and the larvae wander freely about the tunnel-system browsing on the ambrosia-fungus. They do not eat wood or excavate it. When full grown a pupal cell is constructed by the larva at the end of the vertical branch in which it pupates with the head of the pupa facing outwards to the plug of wood-dust closing the cell. The immature beetles feed for some time in the tunnel-system before emerging. They eventually leave the tree through the holes originally bored by the parent beetles.

Logs of all sizes are attacked shortly after they are felled and are inhabited as long as the wood remains sappy. Seasoned or dry timber is not attacked. Beetles are on the wing in India most abundantly in September–November and March–April, less so during the colder months and are very scarce in the hot dry weather. The life-cycle from egg to emerging beetle lasts 2 or 3 months; the emergence-period of a generation is usually completed in 3 months but may extend for 5 months in north India. An attacked log may continue to yield beetles for 8 months from the date of felling.

The following are 5 typical examples of emergences of broods lasting for 2 or 3 months each, shown as monthly percentages of the total population :—

	Feb.	March	April	May	—	Aug.	Sep.	Oct.	Nov.
(a)	1	72	27	0	(d)	.	98	2	0
(b)	2	19	78	1	(e)	.	86	13	1
(c)	.	1	84	15	.	.	.	.	.

In Malaya larvae reach the prepupal stage after 3 weeks and the beetles emerge after 6 weeks from boring in by the parents.

Fig. 98. Gallery-systems of Crossotarsus.

No. 1—Male beetle of *Crossotarsus squamulatus sundri*, natural size 5·7 mm.

No. 2—Main gallery and vertical branch-galleries with terminal pupal cells of *Crossotarsus squamulatus sundri* in vertical sections of *Heritiera fomes*; two separate pieces of wood are placed alongside.

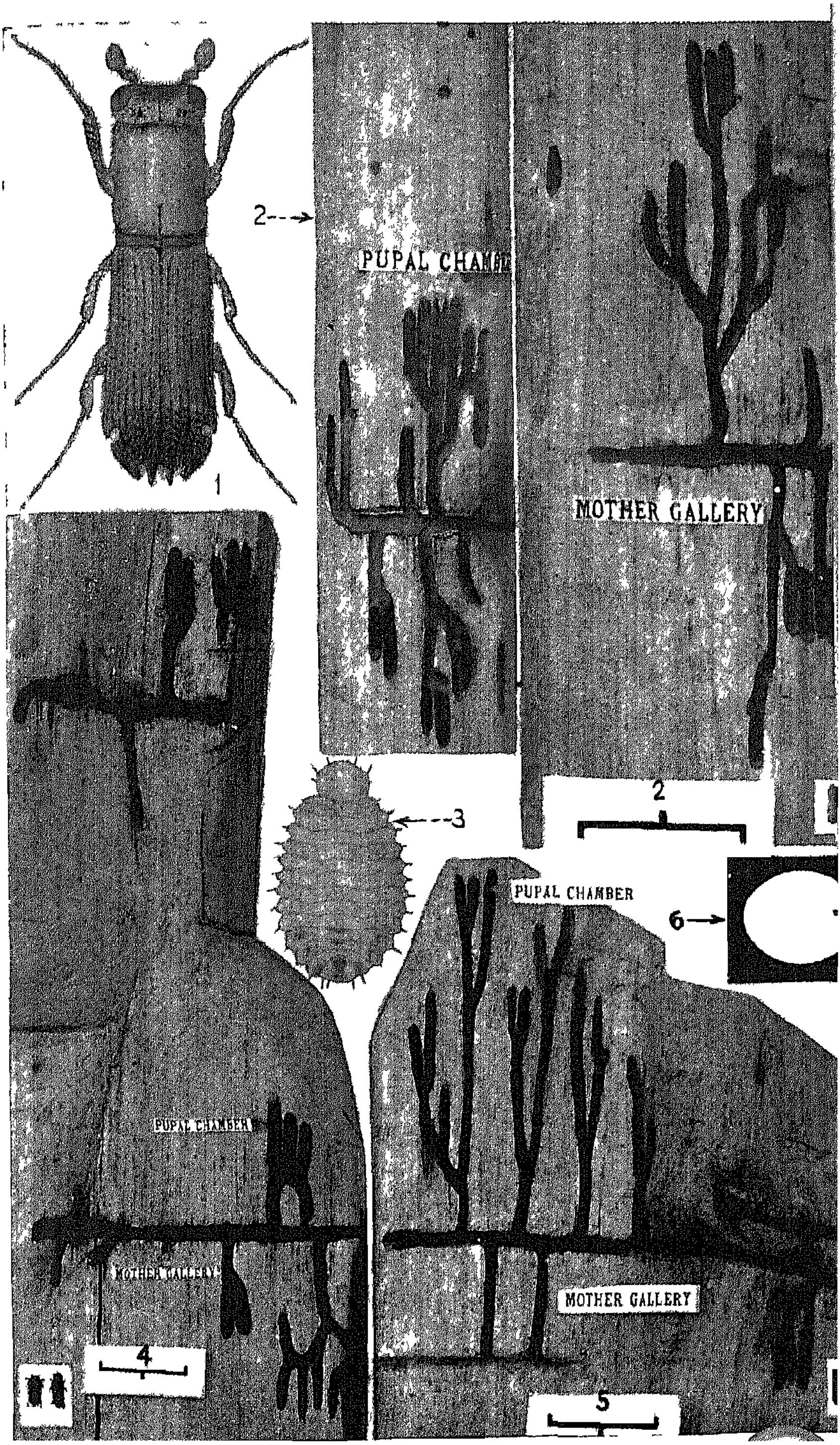
No. 3—Early stage larva of *C. squamulatus sundri*, natural size 2·7 mm.

No. 4—Main gallery and vertical branch-galleries with terminal pupal cells of *Crossotarsus bonvouloiri* in vertical section of *Sapium eugeniaefolium*.

No. 5—Main gallery and vertical branch-galleries with pupal cells of *Crossotarsus cinnamomi* in vertical section of *Cinnamomum cecidodaphne*.

No. 6—Egg of *Crossotarsus squamulatus*, enlarged.

The inch-centimetre scales show the amount of reduction of the photographs of the specimens of wood and beetles in each species.



1
2
PUPAL CHAMBER
MOTHER GALLERY
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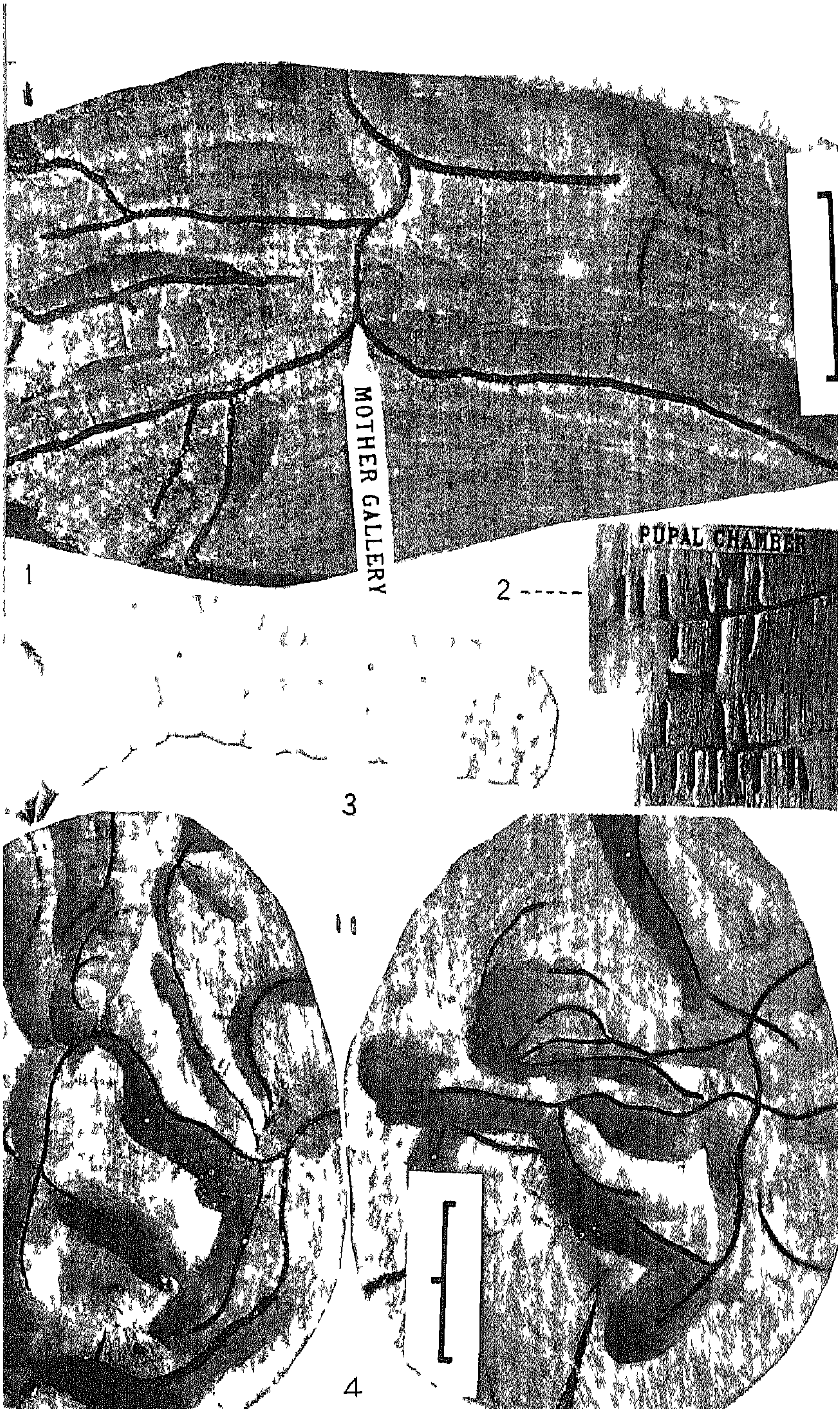
MOTHER GALLERY
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LITERATURE :

Beeson, 1916, *Ind. Forester*, pp. 217-224, plate 16, fig.3, Ambrosia beetles or pinhole and shothole borers.

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Gardner, 1932, *Ind. For. Rec.*, XVII, iii, p. 5, pl. i, fig 10 (description of larva).

Crossotarsus siporanus, 4·1 mm., in *Aporosa globifera*, *Baccaurea parviflora*, *Schoutenia mastersii*, in Malaya.

C. siva, 3·3–3·7 mm., in *Albizzia stipulata*, *Cryptocarya wightiana*, *Engelhardtia spicata*. Bengal to Burma.

Crossotarsus squamulatus

The food-plants of this species in India and Burma (in the subspecies **s. squamuloides** Bees.) are:—*Albizzia lucida*, *A. odoratissima*, *A. procera*, *Alphonsea ventricosa*, *Amoora rohituka*, *Bauhinia malabarica*, *Careya arborea*, *Cinnamomum cecidodaphne*, *Eugenia jambolana*. *Ficus glomerata*, *Lannea grandis*, *Mallotus alba*, *Mangifera indica*, *Melanorrhoea usitata*, *Melia azedarach*, *Talauma hogdsoni*, *Tectona grandis*, *Xanthophyllum glaucum*; and (in the subspecies **s. sundri** Bees.) *Heriteria fomes*.

The food-plants of the subspecies **s. squamulatus** Chap. (also recorded in literature as *fragmentus* Samps.) in Malaya are *Boschia griffithii*, *Bridela tomentosa*, *Calophyllum* sp., *Endospermum* sp., *Koompassia excelsa*, *Ochanostachys amentacea*, *Palaquium* sp., *Parkia speciosa*, *Pasania conocarpa*, *Shorea* spp., *Sloetia sideroxylon*.

This species occurs from Bengal to Borneo. The declivities of males of the subspecies are illustrated in Beeson, 1937, *tit. cit.*, pl. 1 ; the male beetle of *s. sundri*, 5·5–5·8 mm., is shown in fig. 98, No. 1. Its gallery-system is of the normal *Crossotarsus*

Fig. 99. **Gallery-systems of Platypus**

No. 1—Main and branch-galleries of *Platypus curtus* in horizontal or cross-section of *Dipterocarpus pilosus* ; 2 beetles are shown in top left-hand corner.

No. 2—Pupal cells of *Platypus indicus* above and below branch-galleries in vertical section of *Buchanania latifolia* ; 2 beetles are shown,

No. 3—Mature larva of *Diapus furtivus* ; natural size 8 mm. ·

No. 4—Gallery-system of *Platypus uncinatus* in horizontal or cross-section of *Heritiera fomes* ; 2 beetles are shown between.

The inch-centimetre scales show the amount of reduction of the photographs of the specimens of wood.

type with a horizontal main gallery serving vertical branch-tunnels which split into terminal subsidiary branches and end as pupal-cells [fig. 98, No. 2.] The egg of *C. squamulatus sundri* is illustrated in fig., No. 6. The larva, 6 mm., of *squamulatus squamuloides* is described by Gardner, 1932, *tit. cit.*, p. 5, fig. 11 ; the early stage larva of *s. sundri* is shown in fig. 98, No. 3.

Beeson, 1919, *Ind. For. Rec.*, VII, v, pp. 5, 6, Economic importance of sundri borers.
— 1937, *tit. cit.*, *Ent.*, III, 3, pp. 79, 80, pl. 1 (description of subspecies, etc.)

C. terminatus, 3·4 mm., in *Adinobotrys atropurpureus, Dipterocarpus cornutus, Myristica andamanica* and in Malaya in *Aglaia* sp., *Santiria griffithi, Scaphium* sp., *Swietenia macrophylla, Xanthophyllum affine.*

C. venustus, 4·0 mm., in *Acacia decurrens, Cupressus macrocarpa, Elaeocarpus serratus, Eugenia* sp., *Gordonia zeylanica, Litsaea zeylanica, Michelia nilagirica.* The subspecies **v. venustulus** Bees., 3·1 mm., in *Doona zeylanica, Semecarpus gardneri, Warmia triquetra* in Ceylon.

C. verelunatus, 4·1–4·4, in *Artocarpus chaplasha, Bassia butyracea, Pterocarpus dalbergioides, Sterculia campanulata, S. villosa, Terminalia manii* in the Andamans.

C. wallacei, 11–12 mm., the food-plants in Malaya are *Calophyllum* sp., *Endospermum malaccense, Koompassia excelsa, Parkia speciosa, Styrax benzoin.*

C. wilmoti, 4·8–5·4 mm., in *Alnus nitida, Cedrela serrata, Cedrus deodara, Fraxinus* sp. (Kashmir), *Populus ciliata, Quercus incana.* Referred to as *C. fairmairei* var. *wilmoti* in Stebbing, 1914, *Ind. For. Rec.*, p. 618, pl. XLV, fig. 6, 6a.

C. (Carchesiopygus) wollastoni, 6 mm., in *Dyera costulata* in Malaya.

The genus **Diacavus,** closely allied to *Diapus*, comprises species with remarkable secondary sexual characters. The forehead of the female is elaborately adorned with curls and clusters of long yellow hairs; the male has the last abdominal sternite enlarged and concave. The pronotum in both sexes bears large secretory pores and the male elytra have wax-secreting pores. The genus appears to be particularly associated with dipterocarps. The size ranges from about 2·5 to 4·5 mm.

Diacavus assamensis, 3·2 mm., in *Shorea assamica ;* emergence is prolonged for 5 months. **D. atkinsoni** in *Pentacme suavis* in Burma. **D. biporus,** 3·2–3·4 mm., in *Dipterocarpus pilosus, Hopea odorata, Parashorea stellata.* **D. capillatus,** 3·2–3·5 mm., in *Quercus lamellosa.* **D. diaphanus,** 2.9 mm., in *Shorea hypochra.* **D. dipterocarpi** in *Canarium euphyllum, Dipterocarpus turbinatus* in the Andamans.

Diacavus furtivus

Throughout the range of *Shorea robusta*, the only known foodplant.

Beetle: The male beetle, 3·5–4 mm., [fig. 4, No. 45], has head and prothorax black, elytra testaceous-yellow, dark at the apices, which are armed with 5 blunt flat teeth which conjointly produce an embattlement of the apical edge of the elytra. The last sternite of the abdomen is large and deeply concave and serves as a receptacle for the collection and transport of rubbish. The female beetle has the apical margin of the elytra rounded, not dentate. When she flies after emergence, the front of the head is adorned with long yellow hairs growing in 4 groups, the lower pair recurved to the summit of the head and the side pair extending straight outwards; after she has bored into the wood these hairs are shed (see Beeson, 1917, figs. 1–4).

Larva: The mature larva, 8 mm., is shown in fig. 99, No. 3, (see also Beeson, 1917, figs. 5-8 and Gardner, 1932 figs. 21–24). The young larva, 1–2 mm. long, is oval and flattened below, without a patterned and thickened zone on the pronotum.

Life-history

Swarming: The beetles swarm by day in full sunshine, the females seeking for sal trees suitable for colonisation and being followed later in the day by males. The flight is feeble because the wings are flimsy with obsolete veins. Prior to boring in the beetles can run quickly over the surface of bark, using their slender tarsi, and this is the only occasion on which the tarsi are used. Inside the tunnel the tarsi are folded back behind the tibiae, the apices of which are used for walking. The excavation of entrance-tunnel may be started by the male or the female beetle but is taken over exclusively by the female after the tunnel has reached about 10 mm. long. Obviously the long frontal brushes of the female interfere with tunnel-making and they are shed (or broken off) at the beginning of the work.

Gallery-system: The entrance-gallery, main gallery and branch-galleries of one system are bored out in one horizontal plane or cross-section of the log. Fig. 100 shows the layout of the sections of the gallery-systems of two separate families of *D. furtivus* in a log of about 9 inches diameter; in branch-wood or stems of small dimensions the main tunnel may complete the circle or spiral inwards; in crowded infestations the tunnels of neighbouring families are linked in a somewhat intricate network.

Wax-tube: The entrance-hole is prolonged by a slender tube of white wax, finished smoothly within and without, projecting from the bark for 1/8th to 1/4th of an inch [fig. 100]. The wax, an ester of ceryl alcohol, is secreted by a group of numerous minute pores situated in the apical third of each elytron of the male beetle; the fine filaments of wax form a small white disc or scale. The beetle detaches the scales at intervals as they are formed and moulds them by rotary movements of the body into

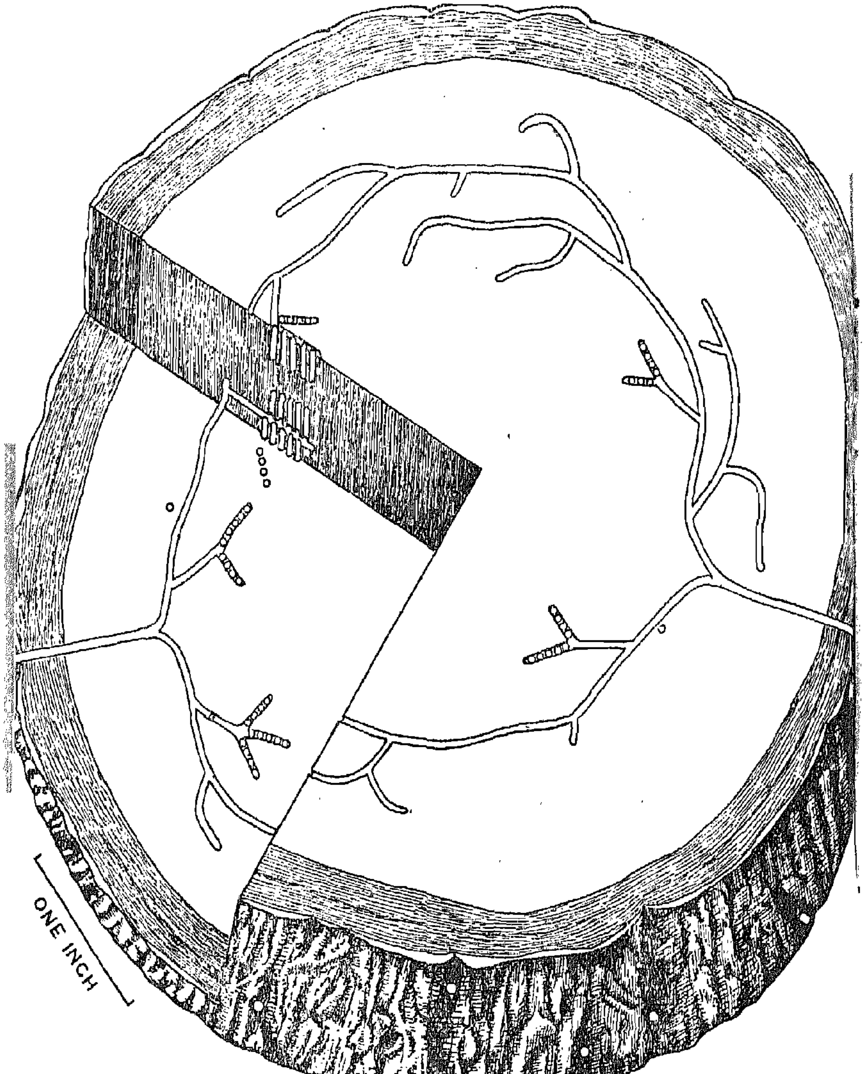

Fig. 100. Gallery-system of Diacavus furtivus.

Cross-section of a log of *Shorea robusta* showing the galleries of two separate families in two horizontal planes, viz., entrance-tunnel with wax tube, main galleries right and left, with branch-galleries, and pupal cells (on vertical radial section). The inch scale shows the amount of reduction; the shaded zone represents bark and bast; the boundary between sapwood and heartwood roughly coincides with the course of the main galleries.

the walls of the tube. One or 2 weeks are required to construct the tube, after which the secretion of wax ceases. The wax tube forms a protective barrier against the entrance of enemies.

O v i p o s i t i o n: On completion of the entrance-tunnel the first batch of eggs is laid and put aside in a branch-tunnel or recess and left to hatch; as many as 40 may be laid before the first batch has hatched; more than 100 eggs may be laid in all. Egg-laying alternates with extension of the tunnel; so the female has to arrange to work at the distal ends of the tunnels, and to clear out the excavated wood-dust, and to shift the eggs to places of safety, and finally to control the growth of the food-fungus.

A m b r o s i a - fungus: The mode of transport and propagation of the ambrosia-fungus has not been completely discovered. It is believed that the frontal brushes serve to carry fruiting bodies; it is also claimed (Beeson, 1917) that spores are carried by the sticky exudation from the pronotal pores. The ambrosia of *D. furtivus* forms a light grey layer of variable thickness covering the wall-surface of the galleries which rapidly turn black. In the course of a week or two the black stain penetrates the surrounding wood-tissue and forms a zone 1/4 to 3/8ths of an inch wide all round the gallery; the black stromatic growth of a fungus blocks up the vessels and medullary rays (it is not drawn in fig. 100).

The excrement of the brood of larvae feeding on ambrosia is in the form of very small pale pellets which dry hard; it is thrown out by the male and forms a dusty granular layer over the ground near the tree.

M a t u r a t i o n a n d p u p a t i o n: The total life-cycle lasts about 10 weeks; the length of the larval period is not known. The mature larva retires to one of the short branch-galleries and bites out a vertical cell above or below at its end. The pupal cell is orientated with the grain in the run of the longitudinal wood-fibres; the second cell is constructed so that its centre is opposite the outer margin of the first cell; the third cell is drilled out alongside the first and the remainder alternate in similar order, i. e., $\frac{1 \quad 3 \quad 5 \quad 7 \quad 9 \quad 11}{2 \quad 4 \quad 6 \quad 8 \quad 10}$ so that the youngest cell is at the end of the branch and farthest from the main gallery [fig. 100]. After excavating the cell the larva turns round completely, seals up the exit-hole with a plug of wood-dust and then pupates. All pupae face with their heads towards the exit. After emerging from the cell the immature beetle feeds in the tunnel where fungus is available. The whole brood emerges through the original entrance-tunnel and the emergence-period extends for 4–6 months.

Economic importance

D. furtivus attacks weakened and dying sal trees, those attacked by *Hoplocerambyx spinicornis* and by the root-fungus *Polyporus shoreae*. Trees with diseased roots are attacked high

up on the bole just below the crown-branches and the attacked zone is not extended to within to 15 feet of the ground until the tree is dead; the gallery-system girdles the tree, its crown-foliage rapidly withers, turns brown and, in a few weeks, falls. The borer is not able to establish successfully in a vigorous tree; resin flows into the tunnels drilled in the sapwood and drowns the beetles.

Technical damage to timber is in the form of small black shotholes and lines in the sapwood and outer heartwood. The black discoloration is much more marked round the tunnels of *D. furtivus* than of any other ambrosia beetles attacking *Shorea robusta*.

LITERATURE:
Beeson, 1916, *Ind. For.*, XLII, pp. 216-223, pl. 16, Ambrosia beetles.
— 1917, *Ind. For. Rec.*, VI, i, pp. 29, pls. 2, The Life history of Diapus furtivus Sampson.

Diacavus impressus, 3·5 mm., in *Alnus nepalensis*, *Quercus incana*, *Q. semecarpifolia* in the Himalayas. **D. hopeae**, 3 mm., in *Hopea odorata*, *Pentacme suavis*. **D. longispinus** in *Dipterocarpus pilosus*, *Pentacme suavis*. **D. serratus**, 2·9 mm., in *Shorea bracteolata*. **D. zeylanicus** in *Dipterocarpus zeylanicus* in Ceylon.

In the genus **Diapus** each mandible of the female frequently bears an appendage projecting forward and forming a pair of tongs or pincers. The size ranges from about 2 to 5 mm.

Diapus brochus, 2·5-2·7 mm., in *Bucklandia populnea*, *Castanopsis hystrix*, *Cryptomeria japonica*, *Lindera pulcherrima*, *Litsaea elongata*, *Machilus edulis*, *M. odoratissima*, *Michelia excelsa*, *Quercus lamellosa*, *Symplocos theaefolia*, **D. capitalis**, 2·7-3 mm., in *Castanopsis hystrix*, *Quercus dilatata*, *Q. glauca*, *Q. lamellosa*. **D. discolor**, 2·4 mm., in *Quercus lamellosa*. **D. himalayensis**, 2·7 mm., in *Alnus nitida*, *Quercus incana*, *Q. semecarpifolia*. **D. minor**, 2·4 mm., in *Castanopsis hystrix*, *Lindera pulcherrima*, *Quercus lamellosa*.

Diapus pusillimus

Balanocarpus heimii, *Dyera costulata*, *Pometia* sp., *Shorea bracteolata*, *S. singkawang* in Malaya. Smith, 1935, gives the food-plants in Australia. One of the smallest platypodids in the region, 1·7-2·3 mm., extends from Assam to Australia. The beetle is chestnut or flavous brown with a narrow transverse slit at the base of the pronotum; the female mandibles bear a pair of sickle-shaped appendages. The egg, 0·4 mm., long, is more elongate than that of *Crossotarsus* [fig. 98, No. 6]. The mature larva, 4 mm., has the prothorax strongly developed.

Life-history

S w a r m i n g: The initiation of the entrance-tunnels in logs is undertaken by the male beetle which bores in sometimes

through the bark but preferably on exposed surfaces of wood, sawn or axed ends, places stripped of bark, etc. The male is joined by the female after 1/4 to 1/2 of an inch of tunnel has been opened up; she waits at the mouth of the tunnel until the male appears pushing backwards the excavated wood-dust. She then grasps the exposed parts of his elytra and abdomen with her forelegs and mandibular appendages and persuades him to come outside the tunnel; after this successful manoeuvre she enters the tunnel and, (presumably having shed the mandibular appendages), takes over the work of cutting at the gallery-head, leaving the male to collect and eject the debris.

Gallery-system: "Should the insect enter exposed sapwood on the side of the log, the burrow is carried directly into the wood for 1 or 2 inches, and then tends to become more intricate. Some main leaders pass straight into the heartwood while subsidiary branches cut across them and link the main leaders until the whole cross-section of the log has been exploited. The burrow-system normally lies in a plane which cuts across the grain of the wood; hence a cross cut often discloses its main features . . . Long sweeping tunnels pass straight into the centre of the log, and in the heartwood subsidiary linkage yields quite a complex burrow system . . . At various depths subsidiary tunnels of no considerable length end blindly in the wood and invariably lead to series of grouped pupal chambers". (Smith, 1935). In small branchwood or in crowded infestations tunnels may be made on the sapwood surface in contact with the bark.

Ambrosia fungus: Shortly after excavation the tunnels begin to show discoloration and eventually turn black. The food of the beetles and larvae consists of ambrosia and sap exudates.

Pupation: The pupal cells are formed in groups above and below the end of a branch-gallery; adjacent cells are almost contiguous as in *Diacavus furtivus* [fig. 100] and they alternate with their opposite numbers.

Emergence: The second generation beetles of *D. pusillimus* do not use the original entrance-tunnel made by their parents which remains blocked by the body of the male. According to Smith (1935) they construct independent exits which are numerous but each serves for the exit of several individuals. The life-cycle has not been determined for Indo-Malayan conditions; in Queensland, Australia the life-cycle takes a year and only a single generation is completed in a log, which may be tenanted for up to 3 years after felling.

Smith J. H., 1935, *Queensl. Dept. Agr. Stock, Div. Ent. Plant. Path.*, Bull. No. 12, pp. 38, figs., The pinhole borer of north Queensland cabinet woods.

Diapus quadrispinatus, the largest of the genus, 5 mm. long, bores in *Alnus nepalensis*, *Castanopsis hystrix*, *Cedrus deodara*,

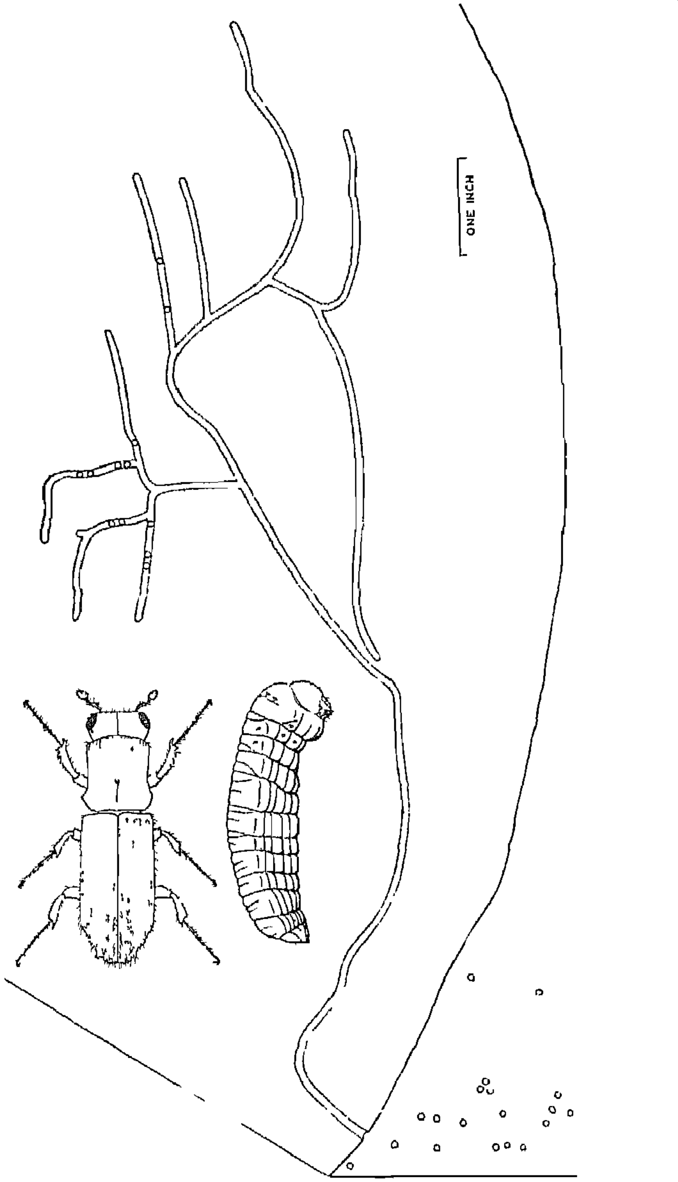

Fig 101. **Platypus biformis, beetle and mature larva, natural size 5–8 mm.** One gallery system is shown projected on to a transverse plane, the circumference and sapwood face of the log being on the righthand side; on the outer sapwood face are groups of entrance holes, similar holes in the branch-galleries (top left) lead to pupal cells; the scale is shown by the one inch line.

Lindera pulcherrima, *Machilus odoratissima*, *Prunus nepalensis*, *Quercus incana*, *Q. lamellosa*.

Diapus quinquespinatus, 2·5 mm., in *Artocarpus chaplasha*, *Canarium euphyllum*, *Castanopsis tribuloides*, *Dipterocarpus pilosus*, *Dysoxylum binectariferum*, *Pentacme suavis*, *Quercus serrata*, *Sarcocephalus cordatus*, *Shorea assamica*, *S. robusta*, *Spondias mangifera*, *Terminalia belerica*, *T. bialata*, *T. manii*, *Tectona grandis* in Indo-Burma. *Balanocarpus heimii*, *Dipterocarpus cornutus*, *D. hasseltii*, *Dryobalanops aromatica*, *Dyera costulata*, *Fragraea gigantea*, *Pometia* sp., *Shorea bentongensis*, *S. bracteolata*, *S. faguetiana*, *S. kunstleri*, *S. leprosula*, *S. parvifolia*, *Sindora* sp., in Malaya where it is considered one of the most important pinhole borers (Browne, 1938). In Assam-Bengal and Burma it is abundant on felling areas boring newly felled timber logs of large size.

Diapus rostratus, 2·5 mm., in *Quercus lamellosa*. **D. spatulifer** 2·5-2·8 mm., in *Beilschmiedia sikkimensis*, *Bucklandia populnea*, *Castanopsis hystrix*, *Cryptomeria japonica*, *Echinocarpus dasycarpus*, *Lindera pulcherrima*, *Litsaea elongata*, *Machilus edulis*, *M. excelsa*, *M. odoratissima*, *Michelia excelsa*, *Nyssa sessiliflora*, *Prunus nepalensis*, *Quercus lamellosa*, *Symplocos theaefolia*.

The genus **Platypus** is the largest in the family and comprises hundreds of species, the beetles of which show much variety in the secondary sexual characters and a range in length from 2-10 mm. Most of the species are polyphagous; palms and conifers are food-plants of some. As far as is known the typical location of the pupal chambers is as shown in fig. 99, No. 2.

Platypus abruptus, 5 mm., in *Quercus incana*. **P. anthocephali**, 4 mm., in *Anthocephalus cadamba* in Bengal. **P. armaticeps**, 2·7 mm., and **P. balanocarpus**, 2·4 mm., in *Balanocarpus heimii* in Malaya. **P. bacillus**, 2·2 mm, in *Castanopsis*, *Macaranga denticulata*, *Sapium eugeniaefolium*. **P. bicornis**, 2·6 mm., in *Albizzia moluccana*, *Artocarpus* sp., *Dipterocarpus* sp., *Pometia* sp., and *Whitfordia pubescens* in Burma and Malaya.

Platypus biformis

A shothole borer of *Pinus longifolia* attacking felled poles and logs and stumps, also living trees of reduced vitality such as fire-scorched poles or exposed moribund seed-bearers or reserved standards in uniform fellings. The beetle usually fails to continue its tunnel from the bark through the sapwood if the tree has enough resistance to pour resin into the cavity and drown it.

The beetle, 5-7·5 mm., [fig. 101], is dark redish-brown with small paired tubercles on the apical declivity.

The larva, 6-8 mm., is described by Gardner, 1932, p. 8, fig. 20, and is illustrated in fig. 101; the pronotal pattern consists of 4 semicircles or V-shaped lines, the inner ones touching a posterior transverse line.

G a l l e r y - s y s t e m : The entrance-tunnel runs for about 2 or 3 inches from the surface into the wood and turns into the main circumferential gallery, which may have a total length of 1 or 2 feet. The layout of the whole system is typically in one transverse plane but it often descends or ascends to other planes, so that the main galleries become spirals and cross their earlier tracks; the long branch-galleries are interwoven with other parts of the system often very densely so that there are 10 to 20 tunnels to the square inch. Fig. 101 shows one plane of a simple pattern in an early stage of development. In crowded colonies long shafts are drilled vertically with the object of getting clear away from crowded spaces to other parts of the wood where new extensions can be made. In pine trees with twisted fibre which have a high degree of spiral twist, the orientation of the tunnels is influenced by the angle of the twist, i.e., parallel to or at right angles to the oblique grain.

Ambrosia-fungus grows on the walls of the galleries and stains the surface black but the discoloration does not extend appreciably into the surrounding wood. Larvae of all instars travel through all sections of the gallery-system grazing on the ambrosia.

The pupal cells are vertically aligned with the grain and are spaced rather widely apart; it is possible that a certain amount of communal pupation occurs in long vertical tunnels.

E m e r g e n c e - p e r i o d : Emergence of the overwintered generation begins in April and May according to elevation and aspect of the pine forests, or as early as March at an elevation of 2,200 feet. These beetles attack at once and their broods mature and the 1st generation beetles emerge throughout the summer and rains; still later broods may not be mature by November and therefore hibernate (as larvae) until the following spring. There are thus two or three generations a year but parts of both the 2nd and 3rd generations may overwinter contemporaneously, being composed of quickly and slowly developing broods. The length of the life-cycle of an individual *P. biformis* is variable seasonally but is about 6–8 weeks at its shortest.

E c o n o m i c i m p o r t a n c e ; Attack in progress is recognisable by the ejection of wood-particles in coherent cylindrical strings often a few inches long or by the outpouring of resin from the bore-holes. It is often very dense—as many as 25 holes to the square inch of a tangential face. Newly felled poles are susceptible to attack immediately after felling and for several months thereafter. Stumps are not attacked until 2 or 3 months after the felling if in spring or for several months if the felling is in autumn. Standing trees and stumps scorched or thoroughly charred by fire are readily bored; a layer of charcoal is not a deterrent as the beetles enter through the cracks. Girdled trees are attacked as soon as they are moribund and are losing the foliage. The bare wood of a

girdle or a blaze is successfully entered only after it has aged and ceased to discharge resin. Slabs and offcuts from dressed logs in pieces 3" to 5" thick usually dry out too quickly to be suitable breeding-material. Small pole and branchwood under 1 foot girth is also unsuitable; apparently a minimum sustained moisture-content is essential for the establishment and nutrition of a brood. Converted timber, sawn or axed, is not likely to be attacked.

Gardner J. C. M., 1932, *Ind. For. Rec.*, XVII, iii, p. 8, fig. 20 (larva).
Troup R. S., 1916, *Ind. For. Mem.*, Silv., I, i, pp. 64, 65, *Pinus longifolia* Roxb., a sylvicultural study.
Turner J. E. C., 1928, *Ind. For. Rec.*, XIII, vii, p. 42, Slash in chir pine forests.

Platypus cavus, 5·1 mm., in *Gluta travancorica* in south India. **P. circumdentatus,** 3·3 mm., in *Machilus macrantha* in Madras. **P. convexicauda,** 2·8 mm., in *Quercus* sp., in Malaya. **P. (Platyscaphus) cordiger,** 3·7 mm., in *Diospyros pyrrhocarpa*, *Dipterocarpus turbinatus*, Andamans to Borneo; the pupal cells are grouped like those of *P. indicus* [fig. 101, No. 2].

Platypus cupulatus, 5 mm., [fig. 4, No. 48, male beetle], a polyphagous species of the Indo-Chinese and Malayan regions, attacks *Bombax malabaricum*, *Croton* sp., *Dipterocarpus pilosus*, *Dolichandrone stipulata*, *Dyera costulata*, *Endospermum malaccense*, *Eugenia glomerata*, *E. jambolana*, *Lannea grandis*, *Parkia speciosa*, *Pterocarpus dalbergioides*, *Shorea eximia*, *S. leprosula*, *S. robusta*, *S. rugosa*, *Swintonia floribunda*, *Tectona grandis*, *Terminalia belerica*, *Xylia dolabriformis*. Timber of large and small dimensions is bored; in logs of large diameter the tunnel keeps to the horizontal plane (at right angles to the axis), penetrates radially for 2 or 3 inches, branches to both sides and runs more or less circumferentially for 6–9 inches, with minor branches on both sides; the diameter of the tunnel is 1·5 mm. The life-cycle occupies about 4 weeks and swarms occur every 5 or 6 weeks in Malaya (Browne, 1935).

P. cupulifer, 5 mm., in *Albizzia lucida*, *Alphonsea ventricosa*, *Amoora rohituka*, *Bischofia javanica*, *Bombax malabaricum*, *Castanopsis tribuloides*, *Dalbergia assamica*, *Dipterocarpus pilosus*, *Ehretia acuminata*, *Ficus glomerata*, *Mallotus albus*, *Meliosma simplicifolia*, *Mesua ferrea*, *Michelia oblonga*, *Shorea robusta*, *Talauma hodgsoni*, *Tetrameles nudiflora*, *Vatica lanceaefolia*. Assam–Bengal–Burma.

P. curtatus, 4 mm, *Amoora wallichi*, *Artocarpus lakoocha*, *Beilschmiedia sikkimensis*, *Eugenia jambolana*, *Livistona jenkinsiana*, *Machilus odoratissimus*, *Quercus lamellosa*, *Shorea robusta*, *Tetrameles nudiflora*..

P. curtus, 3·3 -4 mm., in *Balanocarpus heimii*, *Dipterocarpus baudii*, *D. pilosus*, *D. turbinatus*, *Hopea odorata*, *Koompassia excelsa*, *Shorea bentongensis*, *S. leprosula*, *S. parvifolia*, *S. robusta*, *Swintonia floribunda*. The pupal cells are formed in close rows like those of *Diacavus furtivus* [fig. 100].

P. darjeelingensis, 5 mm, in *Acer campbelli*, *Evodia fraxinifolia*, *Symplocos theaefolia*. **P. decens**, 3·2 mm., in *Castanopsis argyrophylla*, *C. tribuloides*, and *Vatica lanceaefolia*. **P. doonae**, 3 mm., in *Dipterocarpus zeylanicus* and *Doona zeylanica* in Ceylon.

P. engelhardtiae, 3·9 mm., in *Engelhardtia spicata* in Bengal. **P. errans**, 3·4 mm., in *Acrocarpus fraxinifolius*, *Careya arborea*, *Eugenia jambolana*, *Phoebe attenuata*, *Tectona grandis*, *Terminalia myriocarpa*, *Wrightia tomentosa*. **P. eugeniae**, 2·6 mm., in *Eugenia jambolana* in north India.

P. falcatus, 4·8 mm. in *Alnus nepalensis*, *A. nitida*. **P. falcatior**, 4·8 mm., in *Acer campbelli*, *Echinocarpus dasycarpus*, *Elaeocarpus lanceaefolius*, *Evodia fraxinifolia*, *Machilus odoratissima*, *Quercus lamellosa*.

P. forfex in *Anogeissus acuminata*, *Artocarpus elastica*, *Chrysophyllum roxburghii*, *Lannea grandis*, *Spondias mangifera*.

P. forficula, 3·7 mm., in *Artocarpus* spp., *Koompassia malaccensis*. **P. furcatus**, 4·5 mm., in *Acacia decurrens*, *A. melanoxylon*, *Calophyllum walkeri*, *Cupressus macrocarpa*, *Elaeocarpus serratus*, *Eucalyptus robusta*, *Gordonia zeylanica*, *Litsaea zeylanica*, *Michelia nilagirica*, in Ceylon.

P. impariporus, 9–10 mm., in *Dipterocarpus pilosus*, *Mallotus albus*, *Mesua ferrea* in Assam.

P. indicus, 3·5–3·8 mm., in *Alphonsea ventricosa*, *Artocarpus integrifolia*, *Bombax insigne*, *B. malabaricum*, *Dalbergia assamica*, *Dipterocarpus pilosus*, *Ficus asperrima*, *F. bengalensis*, *F. infectoria*, *F. glomerata*, *Meliosma simplicifolia*, *Millettia atropurpurea*, *Poinciana elata*, *Schima wallichii*, *Spondias mangifera*, *Talauma hogdsoni*, *Tetrameles nudiflora*.

The main and branch-tunnels curve sinuously through the soft woods in a horizontal plane and the pupal chambers [fig. 99, No. 2] are offset vertically above and below and spaced slightly apart. The larva, 5 mm., is described in 1932, *Ind. For. Rec.*, XVII, iii, p. 7, figs. 16, 17.

P. insularis, 6·8 mm., in *Koompassia malaccensis*, *Shorea bracteolata* in Malaya.

P. latifinis, 4·3 mm., in *Bombax malabaricum*, *Diospyros paniculata*, *Doona zeylanica*, *Eugenia jambolana*, *Ficus asperrima*, *Lannea grandis*, *Mangifera indica*, *Terminalia belerica*, *T. paniculata* in Ceylon and south India.

P. lepidus, 3·6–3·8 mm., in *Albizzia stipulata*, *Amoora rohituka*, *Castanopsis tribuloides*, *Drimycarpus racemosus*, *Eugenia grandis*, *E. jambolana*, *Ficus glomerata*, *Lannea grandis*, *Millettia pendula*, *Sarcocephalus cordatus*, *Tectona grandis*, *Vatica lanceaefolia*, *Xanthophyllum glaucum* in India–Burma; and in *Adinobotrys atropurpureus*, *Artocarpus lakoocha*, *Elateriospermum tapos*, *Endospermum malaccense*, *Hibiscus* sp., *Parkia speciosa*, *Pithecolobium* sp., *Pometia* sp., *Saraca* sp., *Shorea*

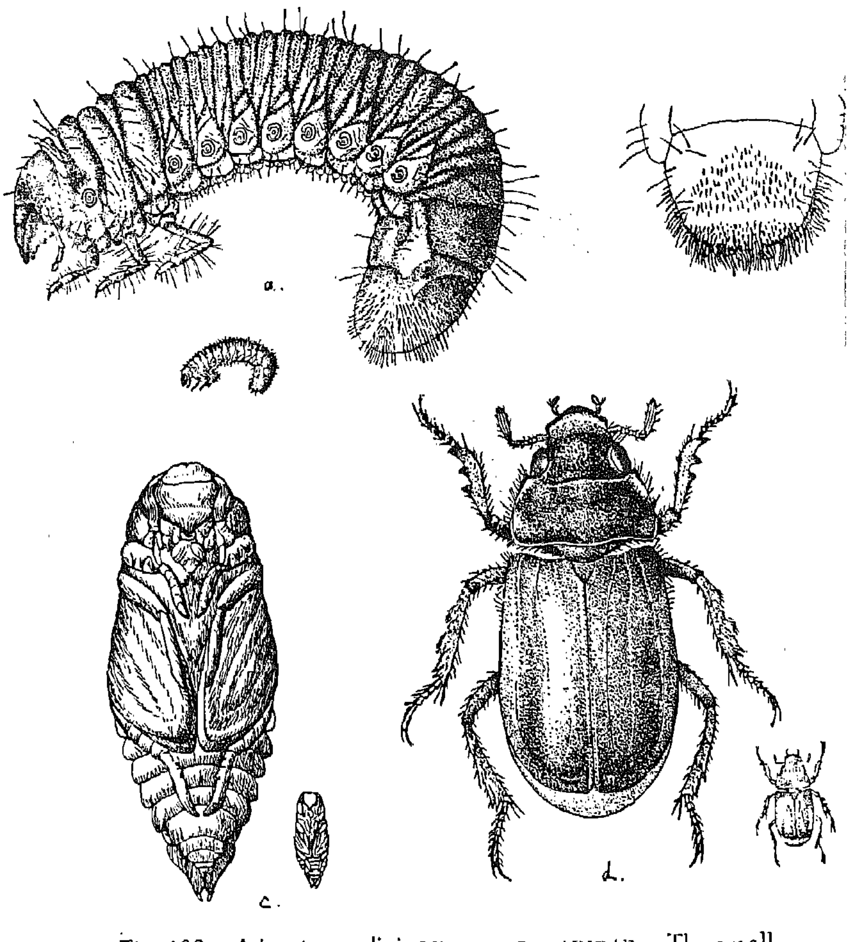

Fig. 102. Adoretus caliginosus, SCARABAEIDAE. The small figures show natural size of larva, pupa and beetle.

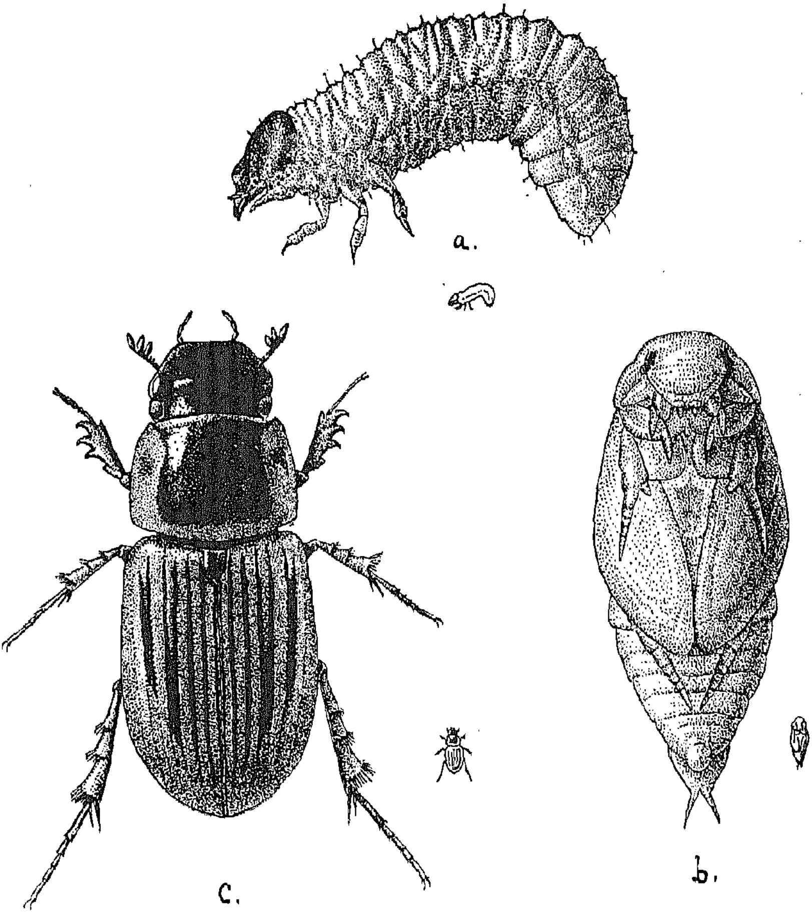

Fig. 103. Aphodius moestus, SCARABAEIDAE. The small figures show natural size of larva, pupa and beetle.

leprosula, *Sterculia macrophylla*, *Xanthophyllum* sp., in Malaya. The diameter of the tunnel is just under 1 mm.; the pattern is of the normal type for the cupulati—the main tunnel parallel to the circumference with minor branches on both sides; the ejected frass coheres in compact cylinders. In Malaya the life-cycle may be completed in one month: larvae are mature in 3 weeks.

P. lopchuensis, 5 mm., in *Beilschmiedia sikkimensis*, *Macaranga denticulata* in Bengal. **P. loricatus**, 5·2–5·6 mm., in *Lucuma malaccensis*, Burma to Malaya.

P. machili, 4·4–4·6 mm. in *Machilus odoratissima*, *Mallotus roxburghianus*, *Symplocos theaefolia*. The larva, 4·5 mm., is described by Gardner, 1932, *tit. cit.*, p. 5, figs. 8, 9 (Crossotarsus sp. n.). **P. malayensis**, 6·5 mm., in *Dyera costulata* attacking tapped trees on the exposed laticiferous surface of the blaze. **P. maritimus** in *Sonneratia apetala* in the Sunderbans. **P. mutilus**, 3 mm., in *Shorea bracteolata*, *S. singkawang* in Malaya.

P. nivalis, 4·4 mm., in *Xanthophyllum* sp. **P. ovatus**, 3·3 mm., in *Swintonia floribunda* in Burma.

P. pasohensis, 2·4 mm., in *Shorea laevis*. **P pernanulus** 2–2·6 mm., in *Pometia* sp. and *Shorea leprosula* in Malaya. **P. piniperda**, 4 mm., in *Pinus khasya* in Burma. **P. protenus**, 2·9 mm., in *Hopea mengarawan* in Malaya. **P. pseudocupulatus**, 3·6 mm., in *Gonostylus* sp., in Malaya. **P. pseudocurtus**, 4·8 mm., in *Shorea leprosula* in Malaya. **P. quadrifissilis**, 2·9 mm., in *Bombax insigne*, *Sterculia villosa*, Andamans to Philippines.

P. rectangulus, 3 mm., in *Anogeissus latifolia*, *Eugenia jambolana*, *Lannea grandis*, *Terminalia tomentosa*, in Burma.

P. secretus, 5·2 mm., in *Acrocarpus fraxinifolius*, *Aesculus punduana*, *Albizzia lucida*, *A. stipulata*, *Alphonsea ventricosa*, *Anthocephalus cadamba*, *Dalbergia assamica*, *Dipterocarpus pilosus*, *Diospyros lanceaefolia*, *D. variegata*, *Lannea grandis*, *Meliosma simplicifolia*, *Ostodes paniculata*, *Sterculia ornata*, *Terminalia belerica* in Burma to Malaya.

P. seni, 6·5 mm., in *Diospyros variegata* in Assam. **P. sexfenestratus**, 4·3–4·4 mm., in *Castanopsis*, in Bengal to Java; emergence continues over 6 months (November–April.). **P. sexualis**, 5 mm., in *Quercus dilatata*. **P. shillongensis**, 4·7 mm., in *Livistona jenkinsiana* and dicotyledonous trees in Assam. **P. shoreanus**, 3·1 mm., in *Anisoptera cochinchinensis*, *Dipterocarpus* sp., *Hopea odorata*, *Shorea assamica*; Assam to Cochin China.

P. signatus, 7·5 mm., in *Artocarpus lakoocha*, *Ctenolophon grandifolius*, *Koompassia malaccensis*, *Lucuma malaccensis*, *Psychotria viridiflora*, *Sterculia macrophylla*, *Xylia dolabriformis* in Burma and Malaya. The main gallery has a diameter of 2·8 mm., and winds round the log in a transverse plane for some distance, later bending down axially. From the axial portion the brood-galleries branch off to right and left alternately, keeping

to one transverse plane but generally curving towards their ends. Above and below these branch-galleries are the pupal chambers (11 mm. long); up to 24 pupal chambers occur in one gallery-system (Browne, 1935).

Platypus solidus

Acacia catechu, *Acrocarpus fraxinifolia*, *Adina cordifolia*, *A. sessilifolia*, *Albizzia lebbek*, *A. odoratissima*, *A. procera*, *Anogeissus latifolia*, *Anthocephalus cadamba*, *Artocarpus elastica*, *A. integrifolia*, *Bombax malabaricum*, *Buchanania latifolia*, *Butea frondosa*, *Canarium strictum*, *Castanopsis tribuloides*, *Chloroxylon swietenia*, *Cinnamomum cecidodaphne*, *Cullenia excelsa*, *Dalbergia sissoo*, *Dipterocarpus pilosus*, *Dolichandrone stipulata*, *Drimycarpus racemosus*, *Duabanga sonneratioides*, *Ficus religiosa*, *F. tsiela*, *Garuga pinnata*, *Hevea brasiliensis*, *Holoptelea integrifolia*, *Lannea grandis*, *Litsaea polyantha*, *Mangifera indica*, *Mallotus albus*, *Pterospermum acerifolium*, *Schleichera trijuga*, *Semecarpus heterophylla*, *Shorea robusta*, *Sterculia villosa*, *Stereospermum chelenoides*, *Tectona grandis*, *Terminalia belerica*, *Tetrameles nudiflora*.

Widely distributed in the Oriental Region and to Australia (possibly introduced); in India it is commoner than *Crossotarsus saundersi* and more frequent in the regions with a dry season. Varietal forms of the male and female have been separately named by Chapuis but the geographical races have not yet been worked out.

Life-history: The male beetle [fig. 4, No. 47, also in photograph of cages for Woodborers, Part Two] is dark brown, 4–5 mm., the apex of the elytra narrowed into bifid awl-like prolongation; the female with a normal rounded elytral apex, body-colour paler and the front of the head pilose. The larva, 6 mm., is described in 1932, *Ind. For. Rec.*, XVII, iii, p. 7, figs. 18, 19; (it resembles generally that of *P. biformis* in fig. 101).

The beetles bore felled or nearly dead trees. Attacks on living but diseased trees, e.g., on rubber, usually fail in places where gum or latex can be poured into the wounds; attacks on resiniferous trees are rarely attempted. The gallery-pattern is of the normal type for *Platypus*, viz., in a horizontal or cross-sectional plane an entrance-tunnel, one or more main galleries parallel to the circumference or the boundary of the heartwood, branch-galleries, and rows of 4 to 6 pupal cells as vertical offsets above and below a branch-gallery (compare introduction and *P. biformis*). The cells are closer together than those of *P. indicus* and recall those of *Diacavus*.

The life-cycle from deposition of the egg to emergence from the wood of the resulting beetle is at its shortest between 8 and 10 weeks in India. It is probable that immature beetles which have left the pupal cells may live in the main tunnels for some time before leaving the wood.

Emergence from an attacked log may take place in most months of the year according to the period and sequence of infestations and may extend upto about 8 months after the date of felling at normal rates of seasoning. The emergence-period of the broods of more or less contemporaneous origin extends from 4 to 10 weeks. Following are typical examples of spring broods expressed as monthly percentages of the total population:

	Feb.	March	April	May	June
(a)	14	75	11	0	.
(b)	.	44	52	4	0
(c)	.	7	73	20	0
(d)	.	.	78	22	0

Economic importance: The pinholes of *P. solidus* are defects in all timbers that are used for their ornamental features; they completely spoil logs intended for peeling for veneers and plywood, and for making match-splints and match-boxes.

Beeson, 1916, *Ind. Forester*, pp. 217-224, pl. 16, fig. 4 f., Ambrosia beetles or pinhole and shothole borers.
— 1938, *Ind. For. Rec.*, Ent., IV, No. 1, pp. 33, 34, Guide to the insects of Dalbergia sissoo.
Gardner J.C.M., 1932, *tit. cit.*, XVII, iii, p. 7, figs. 18, 19 (larva).

P. stilus, 6·3 mm., in *Ficus infectoria* in Burma. **P. subsimilis**, 6-6·3 mm., in *Albizzia moluccana* in Malaya. **P. suffodiens**, 4·8-5 mm., in *Adina cordifolia*, *A. sessilifolia*, *Anthocephalus cadamba*, *Fragraea gigantea*, *Hymenodictyon excelsum*, *Pithecolobium saman*. The emergence-period extends over 3 months in the cold season.

P. transformis, 2·2 mm., in *Dryobalanops aromatica*, *Shorea acuminata*, *S. faguetiana*, *S. lepidiota*, *S. leprosula*, *S. parvifolia*. It attacks large living trees of Malayan species of *Shorea*, boring into wounds.

P. trepanatus, 5·6 mm., in *Gonostylus* sp. in Malaya.

P. turbatus, 6·0 mm., in *Albizzia* sp., *Cassia javanica*, *Polyosma* sp., *Scaphium affine*; Malay Peninsula to Philippines.

P. uncacanthurus, 6 mm., in *Quercus lamellosa*.

P. uncinatus, 3·5-3·7 mm., *Albizzia lebbek*, *A. stipulata*, *Anogeissus latifolia*, *Bassia latifolia*, *Bombax malabaricum*, *Boswellia serrata*, *Bridelia retusa*, *Buchanania latifolia*, *Castanopsis tribuloides*, *Cochlospermum gossypium*, *Diospyros paniculata*, *Dipterocarpus pilosus*, *Doona zeylanica*, *Eugenia jambolana*, *Ficus glomerata*, *Gmelina arborea*, *Heritiera fomes*, *Shorea assamica*, *S. robusta*, *Terminalia belerica*, *T. paniculata*, *T. tomentosa*, *Vatica lanceaefolia*. Throughout the Ceylon-India-Burma-Malaya region. The emergence-period is well-defined lasting for 2½ months.

P. vetulus, 4 mm , in *Dryobalanops aromatica* in Malaya.

P. westwoodi, 6·5 mm., in *Afzelia bakeri*, *Artocarpus lakoocha*, *Dyera costulata*, *Eugenia* sp., *Ficus* sp., *Gonostylus* sp., *Lucuma malaccensis*, *Koompassia malaccensis*, *Xylopia cordata* in Malaya.

SANDALIDAE

THE larvae, 35–45 mm. long, tunnel in rotting wood. In species of **Callirrhipis**, viz., **aequalis, gardneri, incerta, nigrescens,** and **robusta** the life-cycle is annual, the beetles emerging mainly in June. Larval descriptions are given by van Emden, 1936.

LITERATURE ON SANDALIDAE :

van Emden F., 1926, *Rec. Ind. Mus.*, XXVIII, pp. 209-213, pl. 1, Die Sandaliden des Indian Museum in Calcutta.

— 1936, *Ind. For. Rec.*, Ent, II, No. 6, pp. 151-156, Zwei neue Callirrhipis mit ihren larven (Sandalidae).

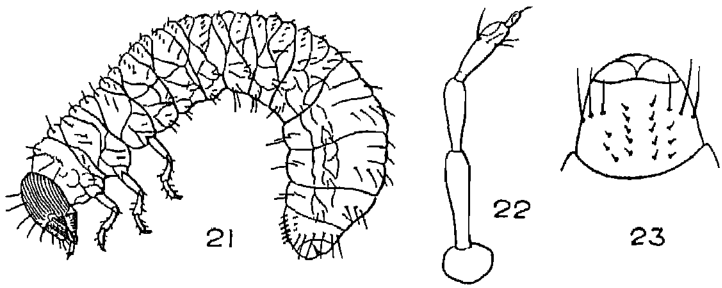

Fig. 104. Larva of Aphodius segmentaroides (natural size about 6 mm.,) Antenna, 22, raster of bristles on 10th abdominal sternite, 23.

SCARABAEIDAE

UNDER the family name SCARABAEIDAE are included several sub-families and tribes which at times have been given higher rank by various authorities. Fowler, 1912, and Arrow, 1910, discuss the classification of the Lamellicornia and the Scarabaeidae in their *Fauna* volumes and their taxonomic conclusions are adopted here. The phylogenetic history of the family is debatable. Fowler (1912, p. 216) considers the Scarabaeidae to be at the head of the Order and the Cetoniinae to be the most developed group and therefore the culminating point of the Coleoptera. We prefer to regard the Platypodidae as the peak of evolution in beetles (see page 324).

The following biological groups can be defined on the basis of food-habits :

1. Larvae live in excrement of mammals, beetles feed on the same (Dung-beetles)—**Aphodiinae, Coprinae, Geotrupinae.**

2. Larvae live in soil or humus (Cockchafer Grubs), beetles feed on foliage or flowers—

   Beetles feed at night—**Melolonthinae**, some **Rutelinae.**

   Beetles feed by day—Some **Cetoninae**, most **Rutelinae.**

3. Larvae live in decomposed or rotting plant-matter (including wood), beetles feed on sap—some **Cetoninae, Euchirinae, Dynastinae.**

THE DUNG-BEETLES AND SCAVENGER-BEETLES:

A group of subfamilies and/or tribes, the **Aphodiinae, Coprinae, Geotrupinae** and others together form an agency of very great importance in the disposal of human and animal excrement and offal, as also in the enrichment of the soil. In tropical forests they do valuable work in quickly mixing raw manure with the soil before the termites gain access to it. Arrow, 1931, doubts whether there is any other large group of beetles which, as a whole, can be pronounced so definitely useful to mankind as the Coprinae. Hingston, 1923, having the Coprinae in mind, estimates that two-thirds of the human excrement of India is carried by scarabs into the substance of the soil; this must amount to something like 50,000 tons of excrement buried *every day* and this quantity does not include the dung of animals which may easily double or treble the amount ".... They seek the excrement of men and cattle, gather it into nodules or rounded pellets and bury it beneath the surface of the soil .... Without their valuable aid the land would be an open sewer .... They are amongst the foremost of the cultivators of the soil. It is not alone that they tunnel through its substance, that they upheave the deeper layers, and thus, in no slight degree, interchange the materials of the ground. Infinitely more important is the fact that they carry down the nutriment to the roots of the plants. They are the vast manurial army of the tropics, the natural fertilising agents of the soil ..... Were it not for Nature's scavengers the East would be the cess-pit of the world. Man assuredly would annihilate himself in the emanations from his own filth .... a slow corruption would ensue and a plague would envelop the land."

The small beetles of the Aphodiinae are in their grade also valuable scavengers of the ordure of men and the droppings of animals, as are likewise the nocturnal Geotrupinae and the Hybosorinae. In the Indian Fauna the genera *Gymnopleurus*, *Scarabaeus* and *Sisyphus* are true ball-rolling scarabs; all other genera are dung-buryers, e.g., *Copris, Caccobius, Onthophagus*, or dung-borers, e.g., *Aphodius* [figs. 103, 104]. The Coprinae are monographed by Arrow, 1931.

THE CHAFER BEETLES:

Cetoniinae: Beetles of the Cetoniinae frequent flowers and foliage on which they feed during daylight; their larvae live chiefly in rotting vegetation or in moist soils rich in humus, and also in decaying wood. The group is monographed by Arrow, 1910.

Dynastinae: The group contains dull coloured but very large beetles one of which, *Chalcosoma atlas*, is perhaps the largest Indian beetle. *Oryctes* beetles damage the growing points of coconut and other palms and species of *Eupatorus* and *Xylotrupes* are suspected of stripping the bark off or girdling stems of young

trees in order to feed on the sap; it is possible that undiagnosed injuries to living shoots and stems resembling hail-scars, gnawing by rodents, bark-cracks, etc., are the work of large dynastine beetles. The group is monographed (Arrow, 1910).

Melolonthinae: This group includes the true "cockchafers" of the genera *Granida* and *Melontha*—plump-bodied beetles 1/4 to 2 inches long, usually light to dark brown in colour, which feed on trees at dusk and do not fly by day. Eggs are laid in the soil, the female often burrowing several inches deep for the purpose. The larva is a large (up to two inches) white grub of the eruciform type, the form of a **C** [fig. 106]. The larval stage is passed in well rotted humus or in the soil at the small roots of the plants on which it feeds. In very cold and in hot dry weather the grubs descend to the deeper levels of the soil; in wet and cool weather they come within a few inches of the surface, but do not leave it to travel above ground as do some species of Cetoniinae. Cockchafer grubs are frequently most injurious in seed beds and in cultural operations, especially in the richer soils; seedlings are killed by the destruction of the rootlets or removal of the bark of the tap-root.

In the subtropical plains the life-cycle is normally annual with a larval period of 8 to 10 months. In the mountains above 6,000 feet the life-cycle lasts 2 years frequently and perhaps always. Many of the species are in all probability polyphagous although only a few food-plants are known.

Rutelinae: Most of the beetles of the Rutelinae are coloured in shades of brown, e.g., *Adoretus*, some *Anomala* [figs. 102, 105] and feed at night like the Melolonthinae but several species are brightly coloured, e.g., *Popillia*, *Mimela* [fig. 4.] and feed by daylight. The group is monographed by Arrow, 1917.

LITERATURE ON SCARABAEIDAE:

Arrow G. J., 1910, *Fauna Brit. Ind.*, Lamellicornia, I, Cetoniinae and Dynastinae, pp. 322, figs., pls 2.

— 1917, *tit. cit.* II, Rutelinae, Desmonycinae, Euchirinae, pp. 387, figs. 77, pls v.

— 1931, *tit. cit.*, III, Coprinae, pp. 428, figs. 61, pls. viii.

Corbett G. H. and Miller N. C. E, 1939, *Dept. Agr, S. S. and F. M. S.*, Sci. Ser., No 5, The identification of the grubs from rubber estates.

Fletcher T B., 1919, *Proc 3rd. Ent. Meet., Pusa*, pp. 165-183, Annotated list of Indian crop pests.

Fowler W. W., 1912, *Fauna Brit. Ind.*, Coleoptera, Introduction, pp. 209-216, figs. 94, 97

Gardner J. C. M, 1929, *Ind. For. Rec.*, XIV, IV, pp. 129, 132, Immature stages of Indian Coleoptera.

— 1935, *Ind. For. Rec*, Ent I, I, pp. 1-33, pls. I-IV, Immature stages of Indian Coleoptera (16) Scarabaeoidea.

Gravely F. H., 1915, *Rec. Ind. Mus*, XI, pp. 497-501, pl. XXII, Notes on the habits of Indian insects, myriapods and arachnids.

— 1919, *tit. cit*, XVI, pp. 265-270, pl. XIV, Descriptions of Indian beetle larvae.

Hingston R. W. G., 1923, *A naturalist in Hindustan*, pp. 209-274, figs.

Paulian R., 1936, *Rec. Ind. Mus.*, XXXVIII, iii, pp. 363-365, The Indian Aphodiinae of the subgenus Trichonotulus.
Silvestri F., 1924, *Rec. Ind. Mus.*, XXVI, vi, pp. 583-586, Description of a new genus of myrmecophilous Scarabaeidae of India.

The ruteline genus **Adoretus** comprises many species (over 100 in India) which are nocturnal defoliators in the beetle stage and are injurious to rootlets of plants in the larval stage. The feeding-pattern of the beetle on a large leaf is characteristic; the leaf-surface is perforated by numerous small irregular holes which *do not cut the* larger veins or the margin but form a lacey network. When feeding the beetle settles on the upper or under side of the leaf not on its edge; the holes are bitten out by the maxillae not the mandibles. The strongly toothed extremity of the maxilla forms the principal biting organ and the hole in the leaf is started by one maxilla scooping or scraping away the layers of cells; it is enlarged by biting off complete pieces from its edge. In the work the maxilla of only one or the other side of the mouth is used (the mouth of *Adoretus* is divided in two by a median process of the labrum). The mandible closely follows the maxilla in all its movements and acts as a sheath or protection (Gravely, 1915). The larva feeds on the roots of weeds and grasses and in rotted vegetable matter; and pupates *in an earth-cocoon* smoothed inside by means of a liquid secretion.

Adoretus bimarginatus, a ruteline beetle, [fig. 4, No. 28] feeds on the foliage of *Bombax malabaricum*, *Cassia fistula* and other trees; it occurs throughout India. The beetle appears in June and July and lives about a month. Eggs take 6 to 15 days to hatch in July. The larva is described by Gardner, 1935, *Ind. For. Rec.*, Ent., I, No. 1, p. 26, figs. 68, 69.

Adoretus caliginosus feeds as beetle on *Cassia fistula*, *Dalbergia sissoo* and other trees and occurs throughout India. Adult life extends to seven weeks. Eggs take 4 to 24 days to hatch in July. The larva is described by Gravely, 1919, *Rec. Ind. Mus.*, XVI, p. 270, fig. It pupates in a cocoon of earth which is smoothed and lined internally with a secretion [fig. 102].

Adoretus duvauceli feeds as beetle on foliage of species of *Bombax*, *Cassia*, *Lagerstroemia*, *Prunus*, *Pyrus*; the species occurs throughout India. **A. epipleuralis** feeds as beetle on *Tectona grandis* in Burma. **A. lasiopygus** feeds as beetle on *Bombax malabaricum* and *Cassia fistula* among other trees. The beetle lives about a month. Eggs take 7 to 16 days to hatch in July. The larva occurs in moist humus soil and in grassland. The species occurs throughout India. **A. simplex** occurs as larva in humus soil and grassland in Kashmir and the Punjab Himalayas. **A. stoliczkae** occurs as larva in humus soil, grassland and in coniferous nursery beds with weeds up to 7,000 feet elevation; the species is also common in the Peninsula.

Agestrata orichalcea, a cetonine, tunnels in the stem of *Pandanus*.

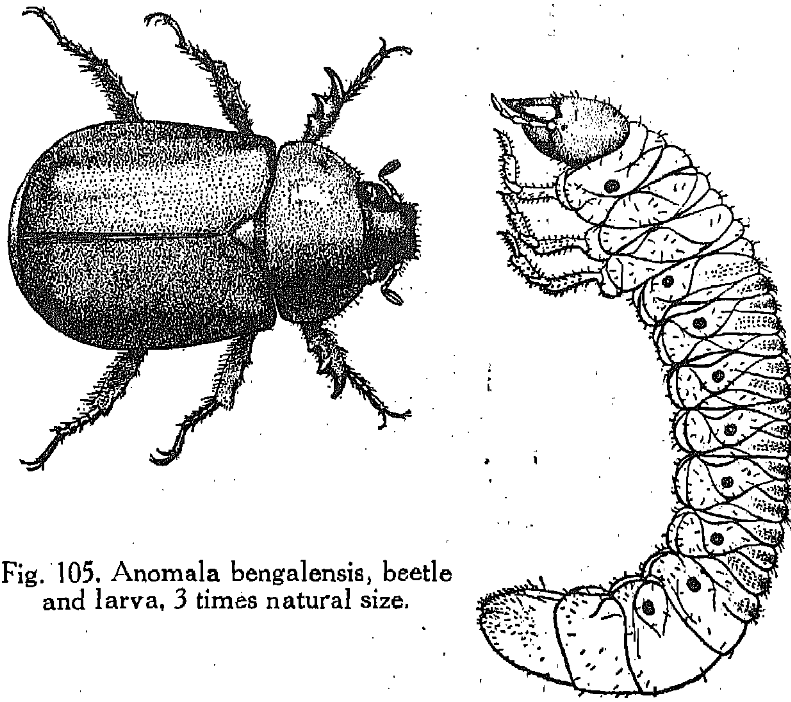

Fig. 105. Anomala bengalensis, beetle and larva, 3 times natural size.

Alissonotum impressicolle, a black dynastine beetle, breeds among the roots of *Imperata arundinacea*, and *Saccharum arundinaceum* grasses and is a pest of sugarcane in Burma and Assam. The life-cycle is annual; eggs in October, November: pupae in April, May: beetles April–November. The life-history and economic importance are given by C. C. Ghosh, 1937, *Ind. Journ. Agr. Sci.*, VII, pp. 907–931, figs. 1–5, 2 plates.

The ruteline genus **Anomala** contains both day-flying and night-flying beetles. Over 200 species occur in India, many of which are probably important pests, but very little is known of their life-cycles. The beetles usually swarm first in May after the earliest heavy showers of rain. Eggs are laid in the soil; the egg, 3-5 mm., increases visibly in size and becomes more spherical as it matures. The larva tunnels through the soil eating the rootlets of plants and rotted vegetable matter, living from about June to March. Pupation takes place in the shelter of the larval skin without the formation of a special cell or cocoon in the soil. The pupal period may last a month and the immature beetle remains in the soil until suitable climatic conditions permit emergence and flight. The generation is ordinarily annual.

Anomala bengalensis, a testaceous-yellow ruteline beetle, [fig. 105], defoliates *Cassia fistula*, *Lagerstroemia* and other

trees. Swarming occurs in May to the latter half of June from dusk onwards. The larvae feed on the roots of grasses and may injure sugarcane. The life-cycle is annual. The species occurs throughout India and Burma. The larva and beetle are figured in *Agr. Res. Inst., Pusa*, Bull. 69, (1919), fig. 5. [fig. 105].

Anomala dalbergiae, as beetle, defoliates *Dalbergia latifolia*. **A. dimidiata**, a large bright green beetle, is a common polyphagous species in the Himalayas. **A. flavipes** and **A. grandis**, as beetles, defoliate *Alnus nepalensis*. **A. lineatopennis**, another mountain species, occurs as larva in seed beds of *Cedrus deodara*; the beetle defoliates plum trees and damages the fruits of apple trees. **A. marginipennis**; the larva occurs in the soil of taungya cultivation.

Anomala polita.

The beetle defoliates various trees, including *Cassia* and *Lagerstroemia*. It is 20 mm. long, testaceous, margined with reddish-black, and occurs throughout India. Beetles swarm at dusk in May–July, the earliest activity occurring soon after the first showers of rain of the monsoon season. Pairing and laying of eggs takes place throughout this period and the initial limits of the generation are correspondingly wide. Eggs are laid at night in soil at a depth of 2 or 3 inches, singly; one female may lay 30 eggs. The incubation-period lasts a week to 10 days during which the egg becomes rounder and heavier increasing in size from $2 \times 1\frac{1}{2}$ mm. to $3\frac{1}{4} \times 3$ mm.

The first stage larva has hatching spines on the metathorax and the egg shell is broken into several pieces at hatching. It feeds in the soil for about 4 months; plant-tissues especially rootlets are eaten and with them also a very large quantity of earth so that the pellets of excrement are almost entirely earth. When full grown, the larva is about 40 mm. long [fig. 106]; it descends deeply to the subsoil and prepares a chamber or cell of consolidated and smooth-lined earth in which it rests throughout the cold season. It pupates in April, the pupa lying inside the split larval skin; after a pupal period of about 10 days the beetle is formed and its subsequent escape from the soil is determined by local showers. The generation is thus annual with the life-cycle sometimes as short as 9 months.

LITERATURE: The life-history of this or a closely allied species is described under the name of *Anomala varians* by H. M. Lefroy, 1910, *Mem. Dept. Agr., India*, II, pp. 143-146, pl. XIV. A summary of this memoir is given by G. J. Arrow in *Fauna of British India*, Rutelinae, 1917, p. 22. The larva is described by Gardner, 1935, *Ind. For. Rec.*, Ent I, No. 1 p. 27, figs. 60-62.

Anomala ruficapilla; the larva occurs in clayish soil with roots and grass. The beetle is testaceous with marginal patches of black. Gardner, 1935, *tit. cit.*, I, i, pp. 27, 28, fig. 65 describes the larva. **A. rufiventris**; the larva occurs in coniferous nursery beds at 6,000 to 7,000 feet; the beetle is bronzy green with the

abdomen mahogony red. The larva is described by Gardner, 1935, *tit. cit.*, p. 27. **A. rugosa** and **A. tristis**, as beetles, defoliate trees in the latter half of June swarming from dusk onwards; larvae occur in rich soil. **A. varicolor** is another species generally defoliating trees in June, July when the beetle lives for about 3 weeks. The egg takes 1 to 2 weeks to hatch in June, July. **A. xanthonota**; the larva occurs in clayey and stoney soil in open spaces in coniferous forest, 6,000 to 9,000 feet. The beetle is yellow above and deep or purplish green below.

Many species of the genus **Aphodius** lay their eggs without any special preparation in dung on which the beetle feeds and in which the larva lives also. Other species feed on fresh cattle dung as beetles but oviposit in the hard dry dung in which the larva bores tunnels and finally pupates either in the tunnel or in the soil below. Common species in the Indian Region are **brahminus, crenatus, fimetarius, moestus** [see fig. 103; in cowdung-fuel-cakes, life-cycle 3 weeks], **parvulus, segmentaroides.** [see fig. 104; in decaying leaves], **sorex, urostigma.** Descriptions and a key to some larvae are given by Gardner, 1935, pp. 10-12, figs. 20-25.

The melolonthine genus **Apogonia** contains several species of small, globular, brown, shining beetles (1/4 to 3/8ths of an inch) that feed on leaves in swarms at night. The larvae feed on the roots of grasses and shrubs.

Apogonia clypeata, a melolonthine beetle [fig. 4, No. 30] eats ragged patches at the edges of young leaves of *Tectona grandis* in Burma. **A. coriacea** occurs in nursery beds in the hills in Ceylon. **A. ferruginea.** The beetle defoliates *Bombax*, *Ficus* and other trees in June, July.

Apogonia granum. The beetle defoliates teak in Burma and in north and central India. Swarming begins with the first heavy falls of rain in May (Burma) and in July (India). Ragged patches are eaten in the edges of the young leaves during the night; by day the beetles shelter in the soil at a depth of a few inches. Eggs are laid in the soil very shortly after swarming and pairing, and the larvae hatch in a few days. The beetles live a long time but die off before the end of the monsoon.

Apogonia nigricans also defoliates *Tectona grandis* in Burma. **A. villosella**; the beetle swarms at the break of the monscon and defoliates various trees. Eggs take 5 to 17 days to hatch in July-August. The larvae occur in rich soil.

Aserica cinnabarina, a melolonthine, occurs as larva in nursery beds of *Acacia melanoxylon.*

Autoserica insanabilis, a melolonthine beetle, defoliates *Tectona grandis*; its larva occurs in soil containing the roots of shrubs.

The hemispherical chestnut red beetles of the geotrupine, **Bolbocerus**, are often attracted to lights; they are scavengers and dung-buryers.

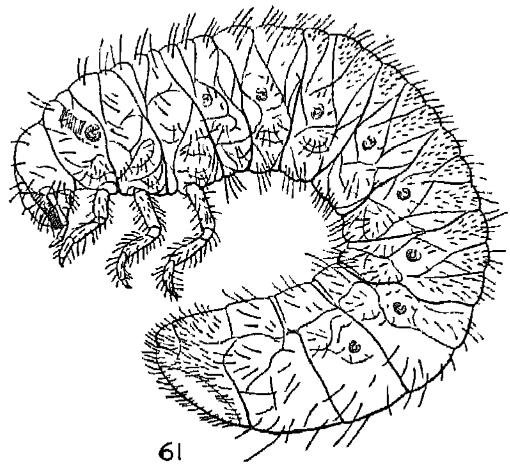

Fig. 106. Larva of Anomala polita, natural size 40 mm.

Brahmina coriacea, a melolonthine beetle, feeds on various trees and shrubs in the Himalayas and is a pest in fruit orchards. The larva, 25 mm., occurs in clay or sandy soil with humus and the roots of weeds, in grassland and meadows, and in fallow land or abandoned cultivation. It also occurs in nursery beds of conifers. A larval description is given in 1935, *Ind. For. Rec.*, Ent., I, i, p. 17, fig. 35.

Brahmina crinicollis; the larva occurs in stiff or stoney soil that has been cultivated in the Himalayas. **B. kuluensis**; the larva occurs in moist sandy soil with grass or weeds under light shade. **Brahmina** spp. occur in the soil of coniferous forests in the Himalayas and in nursery beds.

Cephaloserica thomsoni, a melolonthine beetle, defoliates various trees in the plains of India at the break of the monsoon. The larva occurs in moist or wet alluvial or stiff soil or stoney soil with grass and herbs, also in abandoned cultivation. The beetle lives for two months. Eggs take 4 to 10 days to hatch in July-August.

Cheirotonus see **Propomacrus**

Chiloloba acuta, which is one of the most abundant cetonines throughout India, is a bright green beetle sometimes red or blue, shining, and clothed with yellow hairs. It swarms on flowering plants, particularly leguminous, and grasses. The larva lives in humus and manure and in cultivated land; it is described in 1935, *Ind. For. Rec.*, Ent., I, i, p. 23, fig. 51.

The cetonine genus **Clinteria** of about 25 Indian species includes green, brown or black beetles vividly marked in white or orange spots.

Clinteria klugi is a black and orange beetle about 13 to 17 mm. long [fig. 4, No. 27], the larva of which feeds in rich loamy soil, and has been found damaging the roots of seedling of *Tectona grandis* (in Bombay). The eggs are large and spherical and are laid in the soil. The larva, 20 mm., burrows below the surface of the soil, often throwing out small heaps of dust on coming above ground at night and travelling on its back to other feeding-grounds. Pupation takes place in a mud cell or cocoon. Larval description in 1935, *Ind. For. Rec.*, Ent., I, i, p. 23.

Species of **Copris** use as food the dung of ruminants and take it in large quantities into a chamber in the ground where it is triturated by the female and built up into a big mass and then cut up into several balls each of which receives an egg. The parent beetles remain with the brood while it is maturing. There are about 40 species in India.

Eophileurus planatus, a dynastine, lives in rotten wood including the rotten heart of teak trees.

Eupatorus hardwickei. This dynastine beetle has been observed stripping the bark off the trunk of *Alnus nepalensis*, working vertically up the tree for several feet.

In the genus **Geotrupes** the beetle digs a tunnel under a heap of fresh dung and stores a quantity of it in the tunnel so as to be able to feed undisturbed by other dung-beetles. When ovipositing, the female and the male together dig a cylindrical shaft under or near fresh dung. This shaft widens laterally into a chamber in which a large mass of food is collected and the shaft is thereafter prolonged, often considerably, with several side tunnels which are then filled with dung transferred from the chamber. The relatively large egg is laid at the far end of the side tunnel.

Glycosia tricolor, a cetonine, lives as larva in rotten wood.

Glycyphana horsfieldi, a cetonine, lives as larva in rotten wood of *Bombax insigne*, *Chloroxylon swietenia* and others.

Granida albosparsa, a large melolonthine beetle, is common in the Himalayas upto 9,000 feet. The larva lives in soil varying from poor micaceous soil to black humus soil carrying grass or weeds; it occurs in open or lightly shaded places in coniferous forest, and in cultivated land lying fallow. It is one of the commonest and largest of the cockchafer grubs found in seed beds and nurseries of *Pinus excelsa*, *Cedrus deodara*, etc. Damage to seedlings is most severe during May and June. It is possible the life-cycle may last for 2 years above 6,000 ft. The larva, 45 mm., is described by Gardner, 1935, *Ind. For. Rec.*, Ent. I, i, p. 19, figs. 43, 44.

Gymnopleurus is a coprine genus of dung-ball-rollers, or true scarabs. A quantity of dung is cut away from the mass by a beetle and formed into a ball which is rolled straight away for a considerable distance. The beetle pushes the ball backwards, its

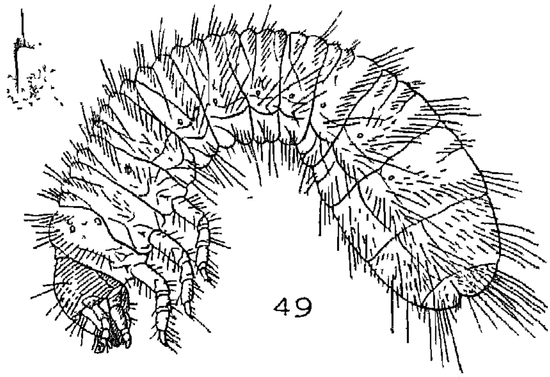

Fig. 107. First stage larva of Heterorrhina elegans, natural size 8 mm. with hatching-spine (enlarged).

long hind legs encircling the ball and its forelegs and forehead pushing against the ground. In some species, e.g., **G. miliaris**, the beetles work in pairs, one pushing and the other pulling, the latter having its hind pair of legs resting on the ground and its fore and middle pair grasping the ball. The dung-ball is buried in an excavation and an egg is laid in it before the shaft is closed. The larval development takes about a fortnight. (see Hingston, 1923).

The giant beetles of **Heliocopris**, some of which are over 2½ inches long, bury dung in globular balls with thick walls of hard cemented earth 2 to 4 inches in diameter. Imprisoned in this cell the larva feeds and pupates and awaits the saturation and softening of the wall by the monsoon rains before it can escape. Up to a dozen such balls may be made and assembled in one place by a single female of **H. bucephalus** who thereby excavates a large quantity of soil. Although called 'elephant dung beetles' these species are not restricted to elephants but have a wide distribution in the Orient.

Heterorrhina elegans, a shining cetonine beetle varying in colour from emerald green, blue and fiery red to black, occurs throughout India, its larva, [fig. 107], 33 mm., developing in rich leaf-mould or in manure. It is described in 1935, *Ind. For. Rec.*, Ent., I, i, p. 22, figs. 49, 50.

Hilyotrogus holosericea, a melolonthine, is one of the cockchafer grubs occurring in seed beds of conifers, and in grassland in the Himalayas.

Holotrichia problematica, a melolonthine, [fig. 4, No. 32], feeds as beetle on the leaves of *Shorea robusta* and many other trees, swarming from dusk to midnight in the latter half of June. The larva damages the root of seedlings, frequently accompanied by *Serica assamensis*.

Holotrichia seticollis is one of the melolonthines swarming at

the beginning of the monsoon and defoliating various trees such as *Cassia* and *Lagerstroemia*

Holotrichia tuberculata, as beetle, [fig 4, No 33, as tuberculipennis] defoliates *Tectona grandis*.

Hoplia advena, a melolonthine, occurs as larva in coniferous nursery beds in the Himalayas.

Idionycha excisa, a melolonthine, is a defoliator in mixed, deciduous forests

Lachnosterna consanguinea, a melolonthine, is one of the cockchafer grubs damaging seedlings of *Shorea robusta* in artificial regeneration. The larva is described in 1935, *Ind. For. Rec.*, Ent I, i, p. 17, figs 36-38.

Lachnosterna longipennis, a melolonthine beetle, is found from 2,000 to 8,000 feet and feeds on the foliage of *Quercus incana*, *Rubus lasiocarpa*, etc., and occurs as larva in nursery beds of *Cedrus deodara*.

Lachnosterna serrata [fig. 4, No. 31], similarly damages seedlings of *Tectona grandis* in agri-silvicultural plots. The species is a pest in garden crops, sugarcane, etc. Beetles occur in May-July and lay eggs in grassy and weedy ground.

Leucopholis pinguis, a large melonthine, is a pest in Ceylon of tree seedlings and nurseries and the beetle defoliates. (1914, *Trop. Agr.*, XLIII, pp. 463-468).

Melolontha furcicauda is fairly common in coniferous forests upto 9,000 feet in the Himalayas, breeding in land bearing grass or herbs and also in areas of abandoned cultivation or fallow fields. The larva is one of the cockchafer grubs occurring in seed beds and nurseries The beetle swarms at the end of June. The larva is described by Gardner, 1935, *Ind. For. Rec.*, Ent, I, i, p. 19, figs. 39-42.

Melolontha virescens occurs at low levels in the Himalayas breeding in moist sandy soil or pure sand of stream beds permeated by roots of grass and herbs. The larva is described *lit cit.*, p. 20.

Microtricha cotesi, a melolonthine beetle, is a general defoliator of the foliage of trees, swarming in the latter half of June, July, after rain. The beetle lives for over one month. The egg hatches in about a week in July. The larva is described *lit. cit.*, p. 18.

Mimela fulgidivittata, a ruteline beetle, defoliates *Quercus incana*. The beetle, a mountain species, is deep green above with red markings as in *M. horsfieldi*.

Mimela horsfieldi occurs at low levels in the Himalayas breeding in moist sandy soil or pure sand of stream beds permeated by roots of grass and herbs The beetle is green above with red markings on the pronotum and elytra. Larval characters are given in 1935, *Ind. For. Rec.*, Ent., I i, p 28, fig 66.

Mimela mundissima occurs in nursery beds of *Cupressus torulosa*, *Eucalyptus maculata*, *E. microcorys* and *Pinus patula*

in Ceylon. Beetles mature in April. **M. passerinii** occurs as larva in very rotten wood and in the moist soil of stream beds throughout the Himalayas. The beetle is green above and coppery red below. **M. pectoralis** is fairly common in the hill country of Burma and in coniferous forests upto 9,000 feet in the Himalayas, breeding in land bearing grass or herbs, and also in fallow fields. The larva is one of the cockchafer grubs occurring in seed beds and nurseries; it is very much like the previous species. The beetle is bright or golden green margined with bright red. **M. pusilla,** as beetle, defoliates *Alnus nepalensis.*

The coprine genus **Oniticellus** includes dung-burying beetles; the larvae of **O. cinctus** and **O. falcatus** are described in 1929, *Ind. For. Rec.*, XIV, p. 129, figs. 67–72, and in Arrow, 1931, fig. 1. The life-cycle takes about 3 weeks.

In the predominant coprine genus **Onthophagus** (200 species in India) habits are varied. The beetle works chiefly in cattle dung in sandy soil unobstructed by rootlets and fibres; it does not carry away the dung to any distance but sinks and cleans out a shaft in the soil immediately below the mass, vertical and perfectly cylindrical and 2 or 3 inches deep. A supply of dung is collected from above and conveyed down to the bottom of the shaft and the beetle feeds on it without interruption. Another shaft is packed nearly full with dung, a single egg is laid and the top is closed with soil. The larva eats about half the store of food and then pupates after about 3 weeks; the young beetle feeds on the remainder of the store before emerging, the total life-cycle lasting about 5 weeks. Hingston gives an account of the habits of **O. capellus** in *A naturalist in Hindustan,* pp. 213–229, pl. X.

Other species of *Onthophagus* make a branching tunnel-system with several egg-shaped dung-chambers at intervals at the ends of each branch. Others feed on carrion and dead insects.

Oryctes nasicornis. The larva occurs in rotten stumps of e.g., *Alnus nitida*, maturing annually in May–July.

Oryctes rhinoceros. The Rhinoceros Beetle.

This dynastine beetle is a pest of coconut and other palms in India, Burma, Ceylon, Malaya and beyond, It does not occur in the Andamans where *Cocos nucifera* is not indigenous and was not introduced until about 1880. Its foodplants are *Areca catechu*, *Cocos nucifera*, *Elaeis guineensis*, *Metroxylon sagu*, *Nipa fruticans*, and *Oncosperma tigilaria*.

Life-history

The beetle is black in colour with reddish-brown pubescence on the under surface; its average size is about 40 mm. long by 20 mm. broad. The anterior two-thirds of the pronotum is occupied by a broadly rounded depression, and there are two blunt

elevations directed forwards in the posterior region. The male beetle has a longish horn on the head and a bare pygidium ; the female has a shorter horn and the pygidium is densely clothed with reddish-brown hairs.

The beetles bore into the crowns of healthy palms particularly the coconut, palmyra and talipot and eat through the unopened young growing leaves, which after they expand show a more or less regular pattern of ragged holes. The fragments of fibre and wood are not ingested. They feed on the sap discarding the fibrous tissue, which often remains plugging the borings. Feeding is done in the early hours of the night; during the day the beetles are inactive and hidden.

Oviposition: About 60 large, white, hard-skinned eggs are laid by a female (size about 3·5 mm. × 2·0 mm.). Eggs are not laid in the tops of palms but in decaying vegetable matter, especially decaying leaves and logs and stumps of palms, rotten or partially burnt vegetable refuse, old cattle dung, wet sawdust, fermenting megass, the waste from oil palms and palm factories (but not in coconut husks). Occasionally larvae may breed in the rotting parts of standing palms still living. The egg hatches in 10 to 20 days.

The full grown larva has an average length of about 75 mm. and breadth of 25 mm. The body widens from the head to the swollen anal segment. It is sparsely covered with short brownish hairs, white except towards the posterior end where the colour is greyish-blue. The reddish brown spiracles are conspicuous on the prothoracic and first eight abdominal segments. The larval feeding-period varies from 70 to 200 days. In south India the average larval period is about 100 days in July and 120 to 140 in the colder months.

Pupation: When ready to pupate the larva leaves the foodstuff and tunnels into the soil sometimes to a depth of a foot and forms an earthen cell, hard and internally smooth. About 7 to 10 days are passed in an inactive stage before pupation. The pupa is rather larger than the beetle it produces; the pupal stage lasts about three weeks. The pupal cell is not immediately vacated and may be tenanted by the immature beetle for two to three weeks.

Life-cycle: In favourable climates the total life-cycle from deposition of the egg to emergence of the beetle lasts four to nine months. The adult lives for as much as 10 months. Egg laying occurs practically throughout the year and in consequence there is no definite sequence of generations but the incidence of attack is highest in the dry season, December to May.

Economic importance

The Rhinoceros Beetle is a serious pest of cultivated coconut palms of all ages by destroying the growing bud, setting up decay

in the wounds and by producing conditions suitable for attack by the Red Palm Weevil, *Rhynchophorus schach.* Palms in the immediate vicinity of breeding-places of *O. rhinoceros* are always heavily attacked, and palms forming a fringe adjoining a new clearing are more damaged than those further removed. The coconut palm is rarely killed by the attack of this beetle but the leaf-surface is considerably reduced, the growth is retarded and the yield of nuts decreased.

For control measures see references below and Part Two.

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Anon. *Annual Administration Reports of the Agricultural Department, Mysore.*

— *Annual Reports of the Department of Agriculture, Burma.*

Oxycetonia albopunctata, a common cetonine beetle, brick red bordered with black and marked with white, length 14 to 16 mm., which frequents flowers for feeding purposes, breeds as larva in decaying leaf-mould and manure. The larva, 30 mm., is described in 1935, *Ind. For. Rec.*, Ent., I, i, p. 22.

Parastasia basalis, a ruteline beetle with a dark red pronotum and black elytra yellow-banded, occurs in south India developing in rotten wood in the larval stage, which is described in 1935, *Ind. For. Rec.*, I, i, p. 25, figs. 54–59.

Phyllognathus dionysius, a dynastine, breeds in soil containing manure or decayed vegetable matter. The life-cycle is annual in the plains of north India; the eggs are laid in June–July in soil and hatch in 5–7 days; the larva feeds on rootlets of plants and organic matter until September and then prepares a hibernation-cell of earth and pupates. The transformation to beetle takes place in October and the immature beetle remains in the cell until the arrival of rains, the following year in May, June.

Lefroy H. M., 1910, *Mem. Dept. Agr., Ind.*, Ent., II, No. 8, pp. 139-143, Life histories of Indian insects (Col. 1), pl. xiii, coloured.

About 80 species of **Popillia** occur in the Indian Region; they are sun-loving beetles, some with flashing metallic colouration.

Popillia cupricollis breeds in open coniferous forests with light undergrowth and gravelly soil throughout the Himalayas. The beetle, a ruteline, feeds on blossoms; it is a brilliant crimson with the elytra metallic orange-red and the under surface green.

Popillia cyanea occurs throughout the Himalayas above 4,000 feet swarming from June to September and feeding on blossoms. The larva occurs in seed beds of *Pinus excelsa* and *Cedrus deodara*; it is described in 1935, *Ind. For. Rec.*, Ent., I, i, p. 28. The beetle is deep blue or nearly black above and beneath. **P. discalis.** The larva occurs in seedbeds of conifers in Ceylon. **P. pilosa** is on the wing from May to September, feeding on *Indigofera dosua* and other flowers—a mountain and submontane species. The beetle is coppery green with the lower surface darker [fig. 4, No. 26].

Propomacrus macleayi and **P. parryi.** The beetle has the head and prothorax green, the elytra dark with irregular spotting in red and orange, the under surface covered with dense yellowish pubescence, the tibiae all strongly spined. Length of body 2½ inches. The male has the fore legs very much elongated. The larva of this euchirinine is a borer of rotten wood in which it pupates, making a cocoon of long fibres of wood woven together and smoothed on the inside. Himalayas, Kumaon to Sikkim. The Euchirinae are monographed by Arrow, 1917.

Protaetia alboguttata feeds as larva in decaying leaf-mould and sometimes occurs in nursery beds. The beetle is deep blue or blue-black with conspicuous white spots, 13–22 mm. long [fig. 4, No. 29] occurring throughout India. The larva, 35 mm., is described in 1935, *Ind. For. Rec.*, Ent., I, i, p. 23, fig. 53.

Protaetia neglecta, a bronze coloured day-flying cetonine beetle, length about 20 mm., with an intricate pattern of fine grey lines, is on the wing in the Himalayas between 5,000 and 10,000 feet from May onwards. It breeds in forest soil under stones and logs, in cultivated soil and occasionally occurs in the seed beds of *Cedrus deodara* and other conifers. The larva progresses on its back when travelling on the surface of the ground. Pupation occurs in a mud cell. The larva, 40 mm., is described in 1935, *Ind. For. Rec.*, Ent., I, i, p. 23.

Rhinyptia indica, a ruteline, occurs as larva in the soil of sal forests feeding on rootlets of seedlings of *Shorea robusta*.

Serica assamensis, a melolonthine, occurs in the soil of taungyas of *Shorea robusta*.

Serica near **umbrinella** occurs in the Himalayas at 6,000 to 9,000 feet passing the larval stages in moist soil with humus and sand or gravel; it also occurs in fallow fields with weeds or grass. Although common near nurseries of conifers it does not appear to oviposit in seed beds.

Schizonycha ruficollis, a melolonthine, a general defoliator at the beginning of the rains when the beetle lives for over one month and the egg hatches in a week or 10 days.

Thaumastopeus pullus, a cetonine, feeds as larva in rotten wood and woody stems like *Euphorbia royleana*.

Xylotrupes gideon, a large dynastine beetle, has been observed

gnawing patches or strips of thin bark from seedlings of *Poinciana regia* and indigo plants. The larva lives in manure heaps and rotted vegetable matter in soil and pupates in an earthen cell. A description of the larva, 60 mm., is given in *Ind. For. Rec.*, Ent., I, i, p. 13, fig. 19.

SCOLYTIDAE

WHEN Stebbing published *Indian Forest Insects* in 1914 he could record the food-plants of less than 50 valid Indian species of Bark Beetles or SCOLYTIDAE, yet, like most forest entomologists, he had especially studied this family. Now food-plants are known for over 300 identified species in the Indian region owing chiefly to the discovery of new insects rather than to the identification of food-plants. There are at least 2,000 named species of Scolytidae in the world, and we know the food-plants of more than half of them; except in a few cases these plants are trees, woody shrubs and lianes. The Indo-Malayan fauna has been identified and described by Beeson, Eggers, Sampson and Schedl.

Beetle: Beetles of the Scolytidae are cylindrical to hemispherical in form and under 1 mm. to over 9 mm. in size; the colour ranges from testaceous to black, and the vestiture from long silky hairs to minute dusty scales. As tunnellers of bark and wood the beetles have adapted parts of the body for excavation, transport and ejection of the waste products of their labour—the boring dust or frass. Modifications for scraping and shovelling affect the hind end or declivity of the elytra which is truncate or impressed and furnished with spines and teeth in great diversity of shape and arrangement; while at work the beetle obtains leverage and stance by means of asperities on the pronotum; secondary sexual characters appear on the front of the head or the declivity, and in some forms *(Coccotrypes, Xyleborus)* the male sex degenerates to a blind, frail, flightless dwarf.

Larva: Scolytid larvae are closely allied in structure and appearance to curculionid larvae, but there is a considerable diversity of habit correlated with structural modification. In larvae feeding on hard tissues there is a tendency to stronger muscle development, the thorax is enlarged to give purchase for the obliquely chisel-shaped mandibles, the muscles of which require a large head-capsule. Larvae, which feed in ambrosia-filled galleries made by the parents and which do not excavate a pupal cell, have sharply dentate mandibles and a smaller head-capsule with weaker muscles. (Gardner).

Ecology

A fundamental feature in the egg-laying habits of the Scolytidae is that the female beetle herself penetrates the bark or wood in order to construct a special gallery for laying eggs; this feature

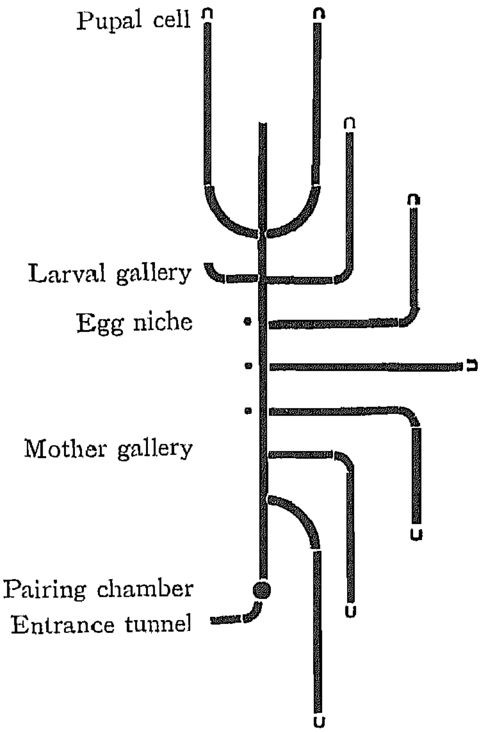


Fig. 108. Gallery-system of a bark-beetle. Diagram of the elements in an axial monogamous gallery-pattern (about natural size).

is also characteristic of the Bostrychidae and Platypodidae. The location and pattern of the brood-galleries can conveniently be used for classifying the biological groups of the family :—

Synopsis of gallery-systems of Scolytidae

(a) **Fruit-borers**—Galleries or chambers for oviposition and larval nutrition excavated in the tissues enveloping the seed and embryo, e.g., *Coccotrypes*, some *Stephanoderes*, *Thamnurgides*.

(b) **Twig or pith-borers**—Mother-gallery and larval galleries run in the juvenile wood or pith of green twigs and herbaceous stems, e.g., *Blastophagus*, *Liparthrum*, *Pityophthorus*, *Xylocleptes*.

(c) **Bark-borers**—The gallery-system essentially lies in the cambium-stratum between bark and sapwood, i.e., most genera.

(d) **Ambrosia-beetles, pinhole and shothole-borers**—The gallery-system is essentially in the sapwood, only an entrance-tunnel passes through the bark, e.g., *Scolytoplatypus*, *Trypodendron*, *Xyleborus*, *Webbia*.

Except in unusual circumstances beetles of these groups establish their broods only in dead or weakly resistant parts of plants (trees); no species dwells in living parts of a plant as a regular habit and without causing its death. (Fruits and seeds are exceptions if ranked as living plants).

The ambrosia-beetles cultivate a fungus for food; the true bark-beetles feed on bark and wood and do not cultivate ambrosia, although wood-staining and disease-causing fungi are incidentally associated with some species.

GALLERY-SYSTEMS OF BARK-BORERS.

Various geometrical classifications have been proposed for the patterns of the gallery-systems of the bark-boring scolytids. The simplest scheme recognises that there are several essential elements in the gallery-system of any species and that the more elaborate patterns are merely repetition and combination of these elements; which are: i. entrance-hole or -tunnel, ii. pairing-chamber, iii. mother-gallery, iv. egg-niche, v. larval gallery, vi. pupal cell, vii, exit-hole.

The entrance of the beetle into the bark is effected through a hole or a tunnel according to the thickness of the bark. On the level of the sapwood is excavated a flat chamber commodious enough for pairing. From this chamber a tubular mother-gallery is bored out between sapwood and inner bark. Eggs are laid at regular intervals in niches or pockets on both sides and the hatched larva bites out a larval gallery away from the mother-gallery. At its end the mature larva pupates in a cell formed in the wood or the bark. The beetle escapes from this cell by an exit-tunnel direct to the outside.

The diameter of any part of the tunnels is slightly more than the diameter of the body of the insect making it. The depth to which the gallery-system is engraved in the sapwood varies in different parts of its pattern and with the species of bark-beetle; consequently the tracks visible on the sapwood-surface or the inner bark-surface after the bark has been stripped off, may be very dissimilar but each half of the mould usually provides a pattern characteristic for the species.

(a) In the simplest pattern an entrance-tunnel leads to a cleared space which starts its functions as a pairing-chamber and later is enlarged to a communal larval feeding-chamber, from which in the still later stages of some species separate mature larval galleries diverge (*Cryphalus*, some *Orthotomicus*).

(b) The primitive system with a definite mother-gallery is one-armed or monogamous and is alined transverse or parallel to the axis of the standing tree. The preceding fig. 108 shows the elements combined in a typical monogamous system, as in *Diamerus*, *Scolytus*, *Sphaerotrypes*.

(c) The elaborated many-armed systems of the polygamous species have up to 8 mother-galleries starting from the pairing-

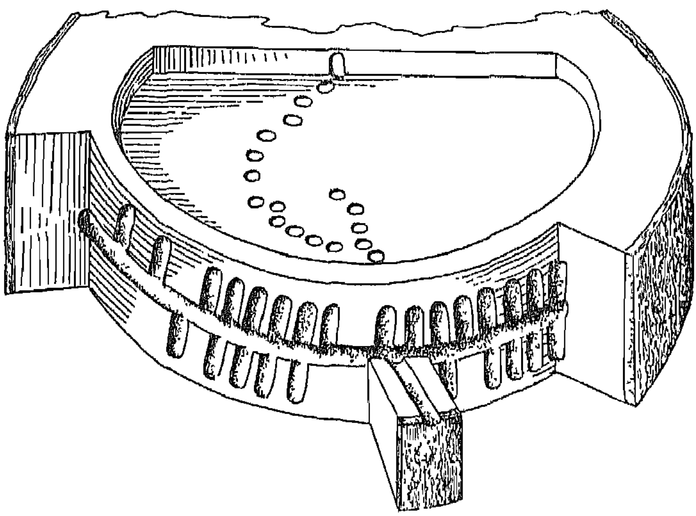


Fig. 109. Gallery-system of an ambrosia-beetle, Scolytoplatypus pubescens, in a small pole, about natural size. The entrance-tunnel leads from the bark to the main circular gallery, above and below which are rows of larval cells (seen in tangential axial section, and, in background, transverse section).

chamber and arranged stellate, or radiate, or transverse, or vertical; also tiered or storeyed from a chamber elongated into a tunnel, e. g., bigamous: *Blastophagus*, *Hylesinus*—trigamous to octogamous: *Carphoborus*, *Dryocoetes*, *Ips*, *Pityogenes*, *Pityophthorus*, *Polygraphus*.

In the monogamous species the female sometimes pairs outside the bark and usually bores the entrance-tunnel alone. In polygamous species the male ordinarily prepares the entrance and the pairing-chamber where he is joined successively by 2 or more females, each of which is responsible for the construction of one mother-gallery and its maintenance. The entrance tunnel is sloped downwards so that bark-dust pushed into it can fall outside; beetles which work in felled recumbent logs adjust the angle of the entrance-tunnel to suit the new centre of gravity. In some species this feature is constant enough to identify if the tree was attacked before or after felling.

The pairing-chamber varies in size, e. g., a flat cavity that suffices for the habitation of one pair *(Sphaerotrypes)* or a broad space serving for the passage of several beetles and the excavated dust of several mother-galleries *(Carphoborus)*.

The mother-gallery may be straight *(Diamerus)*, curved *(Pityogenes scitus)*, or sinuous *(Scolytus major)*, etc.; in some

species it may reach an overall length of 2 feet. Normally it is kept clean of boring-dust and excrement by the female who inhabits it during the period of oviposition and often dies in it. Some mother-galleries are provided at intervals with ventilation shafts from the roof to the outer air.

Regularly along each side of the gallery at its intersection with the cambium the female bites out pits or e g g - n i c h e s and deposits an egg in each, covering it with a pad of bark-dust. This methodical disposition of the egg-niches ensures that the larval galleries start on parallel courses at the safest density which will ensure enough food for each larva and the fullest utilisation of the feeding-space. The oviposition-period is prolonged so that the earliest eggs hatch before the later ones are laid.

In some species the greater part of a l a r v a l g a l l e r y runs within the stratum of sapwood and only the smaller part n the overlying stratum of bark; the food of the larva is therefore mainly wood. In other species the larval gallery runs almost wholly within the bark and scarcely grazes the surface of the sapwood stratum. When the food of the larva is mainly wood the larval tunnels are usually longitudinal, i. e., run with the wood-fibres, and usually start from deep egg-niches, sunk in more or less transverse mother-galleries. The direction of larval tunnels bored entirely in the bark is not influenced by the grain of the bast-fibres and consequently is sinuous or irregular. At the outset the larval galleries run in parallel courses and in later stages they diverge from each other so that their full lengths are completed without intersection or mutual interference [fig. 110]. In spaces overcrowded by the establishment of too many mother-galleries the competition may be severe and fatal [fig. 111]; mutual destruction often results from the competition of larvae in the space between adjacent mother-galleries of a polygamous gallery-system.

The p u p a l c e l l always terminates the larval gallery and may be located wholly inside the bark-stratum or largely, even wholly, within the sapwood.

The e x i t - h o l e is directly over the pupal cell; the exit-holes of the brood of one family outline on the external bark-surface the pattern of its gallery-system.

Gallery-patterns of bark-borers are influenced by the grain of the wood-fibres and the thickness of the bark and consequently the characteristic plan is followed by the beetle whether it is working in a standing bole or a horizontal branch or a recumbent log.

GALLERY-SYSTEMS OF AMBROSIA-BEETLES.

The gallery-systems of the ambrosia-beetles are constructed within woody tissue that is moist with sap and suitable for the cultivation of an ambrosia-fungus. The food of ambrosia-beetles

and their larvae is the mycelium and fructifications of the fungus grown on the walls of the galleries; see the paragraph on the Food of the Platypodidae, page 326, which applies largely to this group of the Scolytidae.

In the genus *Xyleborus* and its allies all the work of boring and cleaning the galleries and tending the brood of larvae is done by the unaccompanied female; the male does not leave the home where he was bred and born.

In the genera *Scolytoplatypus* and *Trypodendron* males with specialised secondary sexual features assist the females in the care of the brood.

Synopsis of gallery-systems of ambrosia-beetles

1. Larvae live freely in and pupate in galleries or communal chambers, all *Xyleborus*.

(a) Galleries mainly confined to a horizontal or transverse plane:
- i. Only tubular tunnels without expanded subsidiary chambers, e.g., *Xyleborus cognatus*, *rodgeri*, *testaceus*. [fig. 119].
- ii. With flat extensive subsidiary chambers in the horizontal transverse plane, e.g., *Xyleborus corporaali*, *leprosulus*, *major*.
- iii. With irregular extensive subsidiary chambers in vertical or axial planes, e.g., *Xyleborus andrewesi*, *shoreae*, *sumatranus*.

(b) Galleries ramifying from one stem in all planes without extensive transverse or axial chambers, e.g., *Xyleborus butamali* [fig. 118], *minor*.

2. Larvae live and pupate each in a larval cell installed above and below the main gallery, e.g., *Scolytoplatypus*, [figs. 109, 113], *Trypodendron*.

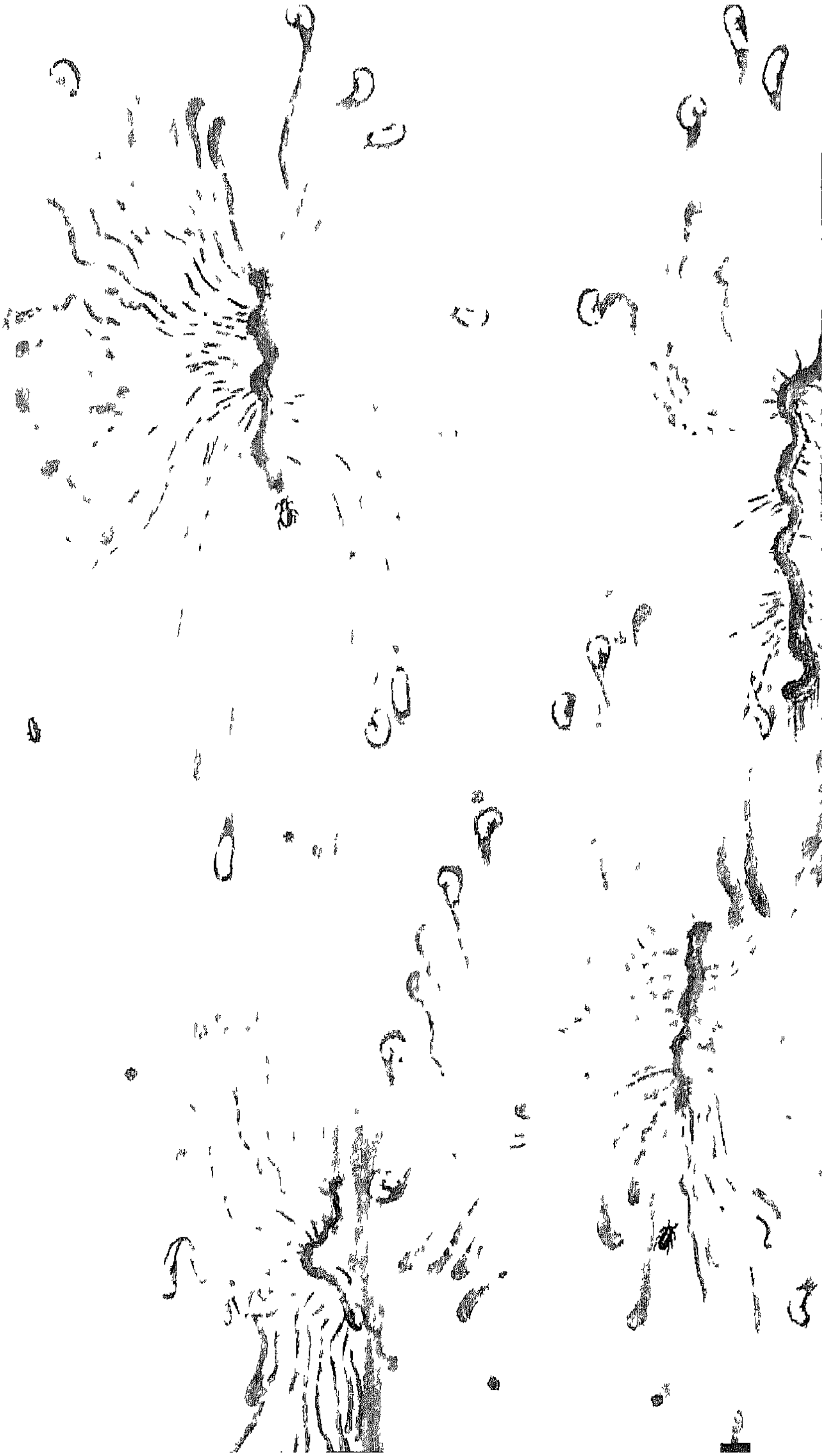
LIFE-CYCLE

L i f e - c y c l e: The duration of the life-cycle of the individual insect has rarely been determined precisely, but it is certain that the variation between the shortest and longest life-cycles in a brood is usually considerable. The following examples illustrate the range:—

Among fruit-borers *Stephanoderes hampei*, the coffee berry-borer, matures in 3 weeks in Java, 4 weeks in Malaya and Ceylon and has at least 8 generations a year in tropical Africa. *Thamnurgides gedeanus* takes about 3 weeks in Malaya.

Shoot-borers (e.g., *Xyleborus discolor* and *X. morigerus*) in a hot environment need only 5–10 days from the egg stage to the

Fig. 110. Gallery-system of Scolytus major as seen on the surface of the bark stripped from a log of Cedrus deodara; the axial mother-gallery is sinuous; the larval galleries are nearly complete, pupation has not begun; natural size.



eclosion of the immature beetle, which, however, is not fit to emerge until it has fed for several days and its integuments have hardened.

True bark-beetles complete their life-cycles in 4–6 weeks in the tropics, e.g., species of *Diamerus*, *Phloeosinus*, *Sphaerotrypes*. In the mountains at about 6,000 feet the life-cycle lasts 2½ months at its shortest, e.g., *Ips*, *Polygraphus*, allowing 3 or 4 generations a year. The average and extreme rates of development of a generation are largely dependent on the condition of the food-material as well as the local weather, and consequently infested material continues to produce beetles over a period of several months, (e.g., *Polygraphus*, *Thamnurgides*) or even throughout the full year (e.g., *Xyleborus minor*, *shoreae*, *testaceus*). Hibernation and aestivation may take place in the larval and the imaginal stages.

E m e r g e n c e - p e r i o d: Well-defined emergence-periods are unusual. In regions with a winter or a well-marked cold season there is a tendency for bark-beetles to swarm in the early spring and early hot weather, but in the tropics any inherent rhythm there may be is obscured by the irregular frequency in the supply of and infestation of breeding-material.

Economic importance.

In the temperate regions the family Scolytidae is of greatest importance to forestry. Epidemics of bark-beetles create a perennial problem for forest management in north America and in North-western Europe, particularly in pure coniferous forests. Millions of board feet of timber have been destroyed and thousands of hectares of forest have been devastated by bark-beetle invasions. In the Indian coniferous forests similar types of scolytids are indigenous but the menace of epidemics rarely appears (for a variety of reasons which are mentioned in Part Two). The tropical and subtropical species of bark-beetles meet with powerful competition from other bark-borers, cerambycids and buprestids, which effectually prevents them from multiplying dangerously in natural forests.

The important scolytid pests in the Indo-Malayan Region are the ambrosia-beetles. One group comprises species of *Xyleborus* which attack living seedling or yearling trees, or living shoots and twigs of older trees. Often the beetles making these attacks result from excessive multiplication in felling-debris or in timber killed by natural calamities, and the danger disappears as soon as the

Fig. 111. Gallery-system of Ips longifolia as seen on the surface of the bark stripped from a log of Pinus longifolia; the axial polygamous mother-galleries, *e*, are very crowded so that larval galleries, *l*, are abnormally congested and starved; *p* is the pairing-chamber, *a* is the aeration-hole; ⅔rds natural size.

capacity of such abnormal breeding-material is exhausted. But there are a few shothole-borers that show a tendency to maintain their populations permanently in living trees, as the shothole-borer of tea, *X. fornicatus*, has succeeded in doing.

Another group, containing the bulk of the species of *Xyleborus* with *Scolytoplatypus* and *Webbia*, breeds only in felled or dying timber and branchwood. The timber is ruined for many purposes by pinholes, shotholes, stain and contigent defects which are produced by these ambrosia-beetles in just the same way as by the Platypodidae (page 327). There are several Indian trees which have a wood suitable for special purposes—in some cases in replacement of imported woods—which are rendered quite useless owing to their liability to pinholing under the current methods of extraction and seasoning.

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Alniphagus padus is a barkbeetle of the twigs and small branches of *Prunus padus* in the Himalayas.

Aphanarthrum royleanum breeds in dead stems of *Euphorbia*

royleana. There are more species of *Aphanarthrum* associated with species of tree-*Euphorbia* in India; otherwise the genus is restricted to north Africa and the Atlantic islands.

Blastophagus khasianus in *Pinus khasya* has similar habits to *B. piniperda*, the Pine Shoot Beetle or Waldgaertner of Europe. In the bark of logs and branches the gallery-system consists of a single, longitudinal, axial mother-gallery with entrance-hole and radiating larval galleries. The young beetles after emergence attack the terminal shoots of the leader and top branches of pine of all ages; a tunnel is bored in the pith for 1 or 2 inches, hollowing out and killing the shoot which dries up and falls. Such tunnels are made for the purpose of feeding and not for laying eggs and are abandoned before the shoot withers. This form of attack causes a high mortality in the *Pinus khasya* at the higher elevations in the Khasia hills.

Carphoborus boswelliae in *Boswellia serrata* (Stebbing, 1914, p. 537, as Cryphalus). **C. costatus** in *Pinus excelsa* and *P. longifolia*. **C. latus** in *Boswellia serrata*. **C. zhobi**, 1·5–1·9 mm., in *Pinus gerardiana* (Stebbing, 1914, p. 496, as Phloeosinus).

Chaetoptelius vestitus, 2·5–3·5 mm., in shoots and branches of *Pistacia integerrima* in the Punjab, a Mediterranean species which breeds in *Pistacia lentiscus*, *P. terebinthus* and *P. vera*.

Cnestus magnus, 3 mm., is a shothole borer of twigs of *Albizzia moluccana*, *Chloroxylon swietenia*, *Swietenia macrophylla* and *S. mahagoni* in Ceylon.

The genus **Coccotrypes** comprises pests of fruit and seeds of trees. See Beeson, 1939, *Ind. For. Rec.*, Ent. V, No. 3, pp. 279-308. The male beetle is wingless, blind and weak, rarely leaving the brood-tunnels. Female beetles bore into the nearly mature or fallen fruit and make short tunnels and chambers in the rind or shell or fleshy envelope of the seed; in large fruits several females find room to establish themselves and their broods. Eggs are laid and the larvae feed in irregular cavities sometimes communally. The infestation may continue for several months and sometimes for the period between the fruiting-seasons. Mature female beetles may leave the bored fruit and shelter in bark, but ordinarily species, which have no alternative breeding-facilities in trees fruiting at different seasons, must pass a period of inactivity sheltering in the old fruit.

Coccotrypes borassi, 2·4–2·7 mm., in fruits of *Borassus flabellifer* and *Caryota urens* in south India and Ceylon. **C. carpophagus**, 1·8–2 mm., in fruits of *Areca catechu*, *Borassus flabellifer*, *Diospyros quaesita*, *Polyalthia simiarum* in Indo-Malaya. **C. dactyliperda**, 2–2·5 mm., in *Areca catechu*, *Cinnamomum zeylanicum*, *Phoenix dactylifera*, *P. rupicola*. Widely distributed by commerce as a borer of the stones of the date palm. The larva is described in Gardner, 1934, *Ind. For. Rec.*, XX, viii, p. 14. **C. elaeocarpi**, 2·5–2·7 mm., in *Elaeocarpus oblongus*, *E. serratus* in

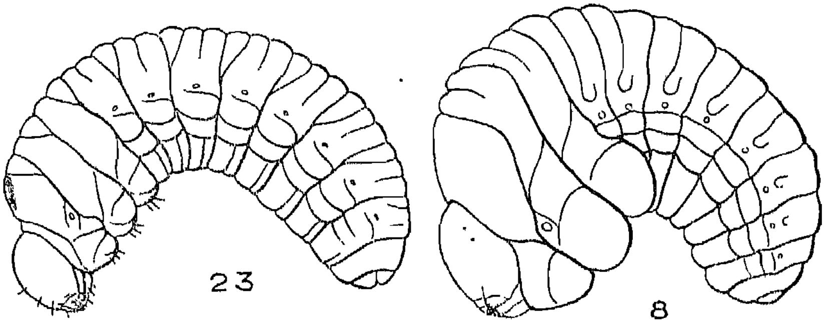

Fig. 112. No. 23. Larva of Dryocoetes indicus, 5·5 mm. No. 8. Larva of Scolytoplatypus pubescens, 5 mm.

Coorg. **C. magnus,** 2·8–3 mm., in *Arenga saccharifera* in Burma. **C. phoenicola,** 1·8–2 mm., in *Phoenix rupicola, P. sylvestris.* **C. theae,** 1·5 mm., in seeds of *Camellia theifera.* **C. trevori,** 2–2·2 mm., in *Areca catechu* in the Nicobars.

Coriacephilus xyloctonoides, 1·5 mm., in *Knema furfuracea* in Malaya.

Cryphalus flumineus in *Alnus nitida* in the north-west Himalayas. **C. major** in *Pinus longifolia* (Stebbing, 1914). **C. strohmeyeri,** 2·3 mm., in *Abies webbiana* (Stebbing, 1914).

Cryptoxyleborus subnaevus, 2·4 mm., a pinhole borer of *Shorea platycarpa* in Malaya. **C. turbineus,** a pinhole borer of *Pentacme suavis, Shorea robusta* in Assam-Burma.

Crypturgus beesoni, 1 mm., in association with the tunnels of larger Scolytidae in *Cedrus deodara* and *Pinus longifolia,* Kashmir to Jaunsar. **C. minimus,** 1·1 mm., in the tunnels of Scolytidae in bark of *Abies webbiana, Cedrus deodara, Picea morinda, Pinus excelsa, P. longifolia* (Stebbing, 1914, as pusillus Gyll.)

Dactylipalpus transversus, the largest of the Indian Scolytidae, occurs in the bark of *Manglieta insignis* and *Mesua ferrea* and in ants' nests.

The genus **Diamerus** includes large robust scaley bark-beetles mainly breeding in figs and allied Urticaceae in the bark of which the female constructs a single long mother-gallery of the simplest type with aeration-holes and with larval galleries that scarcely groove the sapwood.

Diamerus ater in *Ficus* spp. [fig. 4, No. 51]. **D. curvifer** in *Artocarpus integrifolia, Ficus bengalensis, F. mysorensis, F. religiosa, F. rumphii.* **D. fici,** 5·5 mm., in *Ficus elastica* in Bengal. **D. luteus** in *Artocarpus kunstleri ;* the mother-gallery is monogamous, parallel to the axis of the tree, 1¼ to 2 inches long, and from it larval tunnels radiate forming a very regular

oblong pattern; the pupal cells are deep, oval, in the outer bark; the life-cycle takes about a month. (Browne, 1938). **D. naganus** in *Ficus elastica* in Assam. **D. variegatus** in *Ficus bengalensis, F. rumphii,* etc., throughout India. The larva, 5·5 mm., is described by Gardner, 1934, *Ind. For. Rec.*, XX, viii, pp. 6. 7, figs. 17, 18. (as sp. n. near hispidus Klug.) The mother-gallery is axial, long, curved or angled, and provided with aeration-holes.

Dryocoetus coffeae, 2·9 mm., in *Albizzia procera, Coffea arabica, Swietenia macrophylla*, Bengal to Java. The larva, 4·5 mm., is described by Gardner, 1934, *tit. cit.*, p. 13. **D. deobanus**, 4 mm., in *Picea morinda*. **D. hewetti**, 2·5–3 mm., in *Quercus dilatata, Q. incana;* the larva is described by Gardner, 1934, p. 13, [fig. 114]. **D. himalapinorum** in *Pinus excelsa, P. longifolia*. **D. hirsutus**, 2·7 mm., in *Dryobalanops aromatica*. **D. indicus**, 3·8–4 mm., in *Abies webbiana, Picea morinda, Pinus excelsa, P. longifolia*. The larva, 5·5 mm., is described in Gardner, 1934, p. 13, figs. 22–25 [fig. 112, No. 23]. **D. perakensis**, 3·2 mm., in *Agathis alba*. **D. quadrisulcatus**, 2·5 mm., in *Abies pindrow, A. webbiana*.

Epsips sylvarum in dry twigs and shoots of *Clerodendron infortunatum, Ficus rumphii, Flemingia congesta, Mangifera indica*, and lianes. **Ericryphalus artocarpus**, 1·3 mm., in *Artocarpus kunstleri*. **E. discretus**, 1·5–1·8 mm., in *Afzelia bijuga, Exaecaria agallocha*. **E. ficus** in *Ficus bengalensis;* larval characters are given by Gardner, 1934, p. 11, fig. 31. **E. indicus**, 1·8 mm., in *Artocarpus lakoocha, Ficus glomerata, F. rumphii*. **E. litoralis** in germinating seedlings of *Rhizophora mucronata*, in the Andamans. **E. neglectus**, 1·5 mm., in *Hibiscus tiliaceus* in the Sunderbans. **E. simplex**, 1·5 mm., in *Arthrophyllum diversifolia*.

Ernoporus concentralis, 1·4 mm., in twigs of *Dalbergia latifolia*, and *Pterocarpus marsupium* in south India. **E. corpulentus**, 1·5 mm., makes very long, transverse, monogamous mother-galleries in *Kydia calycina*, and *Thespesia populnea;* beetles continue to emerge from the bark of an infested log of *K. calycina* for over a year and in greatest abundance in March, April; the life-cycle may possibly be completed in 6 months or longer periods upto about 15 months.

Estenoborus perrisi in twigs of *Pistacia integerrima* in the Punjab.

Eulepiops glaber, 1·9 mm., in *Artocarpus lakoocha, Xanthophyllum* sp., in Malaya.

Hylastes himalabietis in *Abies webbiana*. **H. khasianus** in *Pinus khasya*.

Hyledius jiri in *Myristica longifolia* in Assam.

Hylesinus fraxinoides in *Fraxinus excelsior hookeri* (Kashmir ash). **H. himalaceri** in *Acer campbelli*. **H. javanus** in *Anthocephalus cadamba, Buchanania sessilifolia, Ficus bengalensis, F. religiosa, Sterculia macrophylla*. The larva, 4 mm., is de-

scribed by Gardner, 1934, p. 12, figs. 27, 28. Widely distributed in the Oriental Region. **H. macmahoni** in *Olea cuspidata* in Baluchistan and Punjab. **H. scobipennis** in *Ficus mysorensis*, *F. tjakela* in south India.

Hylurgus chir in *Pinus longifolia* in Kumaon.

Hyorrhynchus samsinghensis in *Macaranga denticulata*, *Michelia champaca* in Bengal. **H. debrepani** in *Mallotus roxburghianus*. The larvae of two unnamed species of *Hyorrhynchus* from *Acer campbelli* and *Juglans regia* in Darjeeling division are described by Gardner, 1932, p. 8, fig. 19 [fig. 11 b, No. 19].

Hypocryphalus mangiferae, 3 mm., a world widespread bark-borer in *Mangifera indica*. **H. dipterocarpi** in *Dipterocarpus alatus*, *D. pilosus* in Assam-Burma. Larval characters are given by Gardner, 1934, p. 11. **H. striatus**, 1·5 mm., in *Canarium* sp., *Parinarium* sp.. Malaya to the Philippines.

The genus **Hypothenemus** comprises numerous species similar in appearance and habits to the large genus *Stephanoderes*; they are chiefly borers of dying or dead twigs and dry fruits.

Hypothenemus areccae, 1 mm. long, first described from areca nut and probably widely distributed in the Orient in twigs and dried or decayed vegetable matter including seeds. **H. asaroriensis**, 1·4 mm., in dry twigs of *Bischoffia javanica*, *Girardinia heterophylla* and *Spatholobus roxburghii*. **H. aspericollis** in *Bauhinia purpurea* and *Ougeinia dalbergioides* in India; extends from Madeira in the Atlantic to the Austral Islands in the Pacific. **H. erythrinae**, 1·5 mm., in twigs of *Erythrina indica* in Mysore. **H. eupolyphagus**, 1·4–1·5 mm., in twigs and stems of *Aegle marmelos*, *Bombax malabaricum*, *Butea frondosa*, *Calotropis procera*, *Cassia orientalis*, *Cedrela toona*, *Erythrina indica*, *Ficus* sp., *Flemingia congesta*, *Kydia calycina*, *Lannea grandis*, *Luffa aegyptiaca*, *Mangifera indica*, *Ougeinia dalbergioides*, *Spatholobus roxburghii*, *Tamarindus indica*, *Tectona grandis*, *Vangueria spinosa*. **H. tectonae**, 1·2 mm., in shoots of *Tectona grandis* (Stebbing, 1914, p. 536, as Cryphalus). **H. uniseriatus** in twigs or fruits of *Coffea arabica* (berries affected by black rot), *Coffea liberica* (seeds), *Erythrina suberosa* (twigs).

Ips longifolia.

Bark-beetle of the Himalayan conifers, *Abies pindrow*, *Cedrus deodara*, *Picea morinda*, *Pinus excelsa*, *P. gerardiana* and *P. longifolia*, from 2,000 to 10,000 ft.

Beetle chestnut-brown to almost black, 4–5·5 mm., elytral declivity excavate, its sides thickened and toothed, 4-5 teeth, 1st small and sharp, the 2nd and 3rd close together, usually the largest and knobbed, 4th smaller. [Fig. 4, No. 50]. The average size of beetles from the high-level conifers is larger than those orginating in the pines of the lower elevations and hot drier districts.

Life history

Ips longifolia is the Indian representative of a genus characteristic of coniferous forests in Europe, northern Asia, Canada and the U. S. A. where many species are serious pests. It bores into the bark of large tree-trunks, small branches and even the stems of young regeneration on which the bark is relatively thin.

Gallery-pattern: The species is polygamous and the gallery-pattern consist of an entrance-tunnel running straight or obliquely through the bark to the cambium-layer, one or more mother-galleries running for 2 or 3 inches vertically, i. e., parallel to the axis of the stem [fig. 111, e] and joined by a small pairing-chamber [fig. 111, p]. Three mother-galleries in a Y-shape is the commonest pattern but the following combinations frequently occur: $\frac{1}{1}$, $\frac{2}{1}$, $\frac{1}{2}$, $\frac{2}{2}$, $\frac{3}{1}$, $\frac{2}{3}$, $\frac{3}{2}$. The particular pattern appears to be determined by the space available for extension when the female is excavating rather than by a hereditary instinct. In these galleries [fig. 111, e] holes or recesses are drilled through to the outer bark either completely or incompletely and ceasing with the thin lamella perforated by a small central hole; the number varies from 1–5, normally 2 or 3 per gallery. These are termed aeration-holes [fig. 111, a]; the incomplete short cavities are probably used as turning-bays. Along each gallery on opposite sides 30 to 60 eggs are laid in niches. The larvae eat out their galleries [fig. 111, l] in the bast, often sinuous and returning on their own tracks. The large, squarish pupal cell is opened out in the bark at the end of the larval tunnel. The maturing beetle bores from the pupal cell through the bark in order to escape. In a crowded attack, as shown in fig. 111, practically all the available surface and depth is occupied and converted to dust. A mother-gallery may be as much as 5 inches long and sinuous; it grooves the sapwood-surface fairly deeply and its egg-niches are also more than half sunk in the sapwood. A larval gallery rarely has a chance to follow a straight course to its optimum length.

When *Ips* infested bark is stripped from a log the mother-galleries and pupal chambers are revealed as cleared of wood-dust and the larval galleries as packed tightly with red bark-dust. Dust which is ejected to the outside through holes in the bark is derived from the mother-galleries.

Life-cycle: The length of the life-cycle of *Ips longifolia* varies very considerably according to the climate and elevation of the forest. In the warmest localities, e.g., at 2,500 feet it is likely that there are 4 generations per annum. The overwintering generation develops from oviposition in October-November and is mature at the end of March and early in April. The first generation of the year can be completed by the end of May, and the second towards the end of July and the third at the end of

September. Intermediate broods of all generations are produced and consequently there is no well-marked swarming-period after the early flights of spring. It is in the *Pinus longifolia* forests that the insect is capable of most rapid multiplication. At the highest elevation it is possible that there is only one full generation a year.

Economic importance

The large pine bark-beetle is a species that normally breeds in dead or felled trees, and in their branchwood and logs. It is not a regular primary pest of large standing trees, nor does it frequently occur in extensive epidemics as do so many of the coniferous scolytids of North America or Central Europe.

Fire: In fire-killed pine forests it does not multiply readily and avoids trees which fire has dried up. During the period of widespread incendiarism in the coniferous forests of the Punjab and the United Provinces a large proportion of the fire-killed timber remained untouched by *Ips longifolia* and no general bark-beetle epidemics developed. The conflagrations caused by the incendiaries were so thorough that the ground-cover and woody debris and dead standing trees were all consumed; it is probable that fire on these occasions destroyed all the *Ips* breeding-material and acted as a control measure.

Controlled burning in pine forests in the Himalayas is a practice which varies considerably in its effect on the bark-beetle population. Properly controlled burning is advantageous and destroys the borer-population in small branchwood and twigs and in felling-refuse of small dimensions. Departmental burning which scorches or kills the lower branches of pine regeneration and pole woods is, on the other hand, a cause of increase in the population of bark-beetles. Species of *Pityogenes* and *Polygraphus* attack the scorched twigs and branches, kill them and extend their attacks to large branches and the stems of saplings, which start to die off. These moribund conditions invite attack by *Ips longifolia* which establishes itself in the poles and thick barked stems.

Uniform system: In the early years of the conversion of irregular unevenaged coniferous forests into uniform evenaged crops there were frequent outbreaks of *Ips longifolia* in primary epidemics. Perfectly healthy advance growth and saplings of *Pinus longifolia* were attacked and killed off in thousands over extensive areas covering whole compartments; trees from the smallest sizes upto about 25 feet were all equally unresistant to mass-attacks, and succumbed in 4 to 6 weeks within the period of one generation of *Ips*. Outbreaks of this type originated on regeneration areas and near fellings. The concentrated fellings produce excessive refuse in which one or two generations of the beetles can multiply, but which dries out in the course of a winter

or a summer and becomes unsuitable for further broods. The local concentrations of bark-beetles are thus forced to attack living trees, and they find the advance growth and the young poles offer the least resistance.

Similar primary attacks on patches in young woods occur in association with thinnings that are not extracted, right-holders, cuttings, wind and snow-break, etc. The centre of fatal attack is usually surrounded by a zone of failed attacks marked by trees displaying many dead beetles entombed in resinous bark.

For control measures see Part Two.

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Ips onerosus, a polygamous stem and branch bark-borer of *Alstonia scholaris* in Malaya. **I. shanorum**, 5·5 mm., in *Pinus khasya*.

Lepicerinus indicus in *Moringa pterygosperma*, *Vallaris heynei*. The larva, 2·5 mm., is described by Gardner, 1934, pp. 10, 11, fig. 26 (as Cryphalomorphus sp.).

Liparthrum artocarpus in *Artocarpus integrifolia* twigs in India. **L. longifolia**, 1 mm., in *Pinus longifolia* twigs.

Orosiotes brevior, 1·7 mm., in *Artocarpus kunstleri*. **O. grossepunctatus**, 1·9 mm., in *Canarium* sp. in Malaya. **O. pini** in *Pinus khasya* and *P. massoniana* in Burma–Hongkong. **O. swintoniae**, 1·9 mm., in *Dipterocarpus pilosus*, *Pentacme suavis*, *Swintonia floribunda* in Assam-Burma. **O. subacuminatus**, 1·9 mm., in *Elateriospermum tapos* in Malaya. **O. terminaliae**, in *Terminalia myriocarpa* in Assam, has a prolonged emergence-period from May to October with the maximum abundance in July (30 percent).

Orthotomicus khasyapini in *Pinus khasya*. **O. perexiguus** in *Ficus religiosa*.

Ozopemon cylindricus, 5·5 mm., a shothole-borer in *Artocarpus lakoocha* in Assam. **O. laevis**, 4·5 mm., in *Hopea odorata* in Cochin China. **O. rugatus** in *Koompassia malaccensis*. Large chambers are formed in the outer sapwood (Browne, 1938).

Phloeosinus conodaphne, a bark-borer in *Litsaea polyantha*. **P. jubatus** in *Cupressus torulosa*. **P. litsaeae** in *Litsaea chinensis*

in India. **P. machili** in *Machilus odoratissima*. **P. malayensis,** 2·8 mm., in *Knema furfuracea*, *Pterocymbium* sp. **P. phoebe,** in *Phoebe lanceolata*, makes a monogamous, axial mother-gallery, and the larval galleries also groove the sapwood.

Pityogenes perfossus in *Picea morinda*.

Pityogenes scitus

Beetle 2 mm., in *Cedrus deodara*, *Picea morinda*, *Pinus excelsa*, *P. gerardiana* and *P. longifolia* in the Himalayas and Baluchistan.

Life-history: The gallery-pattern is polygamous, a pairing chamber about 3 mm. wide, from which upto 5 rarely 6 mother-galleries radiate to all sides in simple or bisinuate arcs of which the maximum length is about 15 mm. In large branches the pattern of the mother-galleries can occupy a circular or broadly oval space; in small twigs their number is necessarily reduced and their direction is forced to be axial or spiral. These galleries and the pairing-chamber groove the sapwood nearly to half their diameter; the egg-niches which fringe the galleries are equally deeply pitted. The larval galleries reach a length of 20 mm. but do not graze the sapwood and leave no trace when the bark is removed; about 15 eggs are laid by each female in a full length mother-gallery. A depression in the surface of the sapwood at the end of the larval gallery marks the site of the pupal cell. Above it in the bark a short exit-tunnel is made by the escaping beetle.

A life-cycle at average rate in the lower elevations of its habitat, e.g., 6,000 feet, takes about 2 months and there are probably 4 generations a year in sequence.

Economic importance: *P. scitus* can bore into the thin green bark or rind of living branchlets and stems of young and old trees. The beetle is able to resist moderate exudation of resin and to carry its tunnels through bark in which resin is abundant and fluid; the entrance-hole is usually marked by a thick ring of white and hardened resin. By the time the generation is complete in a thin branchlet the bark has shrivelled and irremovably adhered to the wood.

Normal breeding-material is small branch and stem-wood of young saplings and seedlings, particularly of *Pinus excelsa*, killed or dying for other reasons. It attacks material injured by snow, or barked by bears, or scorched by ground-fire or struck by lightning, etc. When they have multiplied excessively the swarms of beetles attack in mass-formation young healthy plants in advance growth, new regeneration or young poles. Broods that have originated in one species of conifer can establish themselves in another species; the attacked plants succumb quickly and the needles wither and turn brown. In such mass-attacks there is usually a central point or focus at which trees are heavily infested and killed outright, surrounded by a zone in which trees take much longer to die or are resistant; the latter may be defeated by

subsequent generations if the local multiplication of the population of bark-beetles continues. Other species of Scolytidae which accompany *P. scitus* under these conditions are *Polygraphus* spp. and *Pityophthorus* spp. Working together they can kill progressively larger poles and trees of average height.

In addition to the breeding-material formed by natural agencies there is also that produced by departmental activities such as:—controlled burning which kills or scorches lower branches: girdled trees the dead branches or crowns of which crash on to young stands of conifers; the refuse of right-holders' fellings; lopping and cross-cutting of windfalls to clear roads, etc. *P. scitus* is the most dangerous of the contributory factors in an epidemic of bark-beetles originating with ground-fires.

Gardner, 1934, *Ind. For Rec*, xx, viii, pp. 9, 10. figs. 14 (larva).
Stebbing, 1914, *Ind. For. Ins.*, pp. 562-567 (illustrations, as coniferae Stebb.)

The genus **Pityophthorus** and its allies comprise numerous species of very small beetles that bore in the epidermis or mine in the pith of green twigs and top shoots of many species of trees in all parts of the world. They are often the earliest arrivals on a dying or injured tree and from the progress of their brood-tunnels can be obtained symptomatic evidence of the health of the tree.

Pityophthorus cedri in *Cedrus deodara*. **P. chilgoza** in *Pinus gerardiana*. **P. chir,** 1·4 mm., in *Pinus longifolia*. **P. deodara,** 1·8 mm., in *Cedrus deodara*. **P. gerardianus** in *Pinus gerardiana*. **P. glutae** in *Gluta travancorica*. **P. himalayensis,** 1·5 mm., in *Cedrus deodara*. **P. kashmirensis** in *Abies pindrow*. **P. pindrow** in *Abies pindrow*. **P. sampsoni,** 1·7 mm., in *Pinus excelsa*.

Poecilips apicatus, 1·5 mm., in bark of *Acrocarpus fraxinifolia* and *Macaranga denticulata* in Bengal. **P. fallax,** 2·5 mm., in *Carapa obovata* (fruit), *Ceriops candolleana, Rhizophora conjugata, R. mucronata*. The beetles bore into the green living seedlings of Rhizophoraceae in mangrove swamps from Bengal to Java. The short entrance-tunnel in the radicle of a fallen seedling leads into a small chamber or irregular excavation in which 10-20 eggs are laid and larvae feed communally. Several colonies inhabit one seedling. **P. sierraleonensis,** 1·8 mm., in *Coffea liberica* (fruits), *Mangifera indica* (fruit stalk), *Poinciana regia*, (pod). Africa and south India. **P. silvestris** in *Acacia pennata*, *Spondias mangifera* in India.

The genus **Polygraphus** is cosmopolitan and its representatives thrive in tropical and alpine climates, in evergreens and in deciduous broadleafed trees and in conifers. Most of the species are polygamous.

Polygraphus anogeissi in *Anogeissus acuminata* in Burma. **P. aterrimus,** 3·2 mm., in *Abies webbiana*, *Cedrus deodara*, *Picea morinda* and *Pinus excelsa*. It breeds in logs and branches of

large dimensions which are dead and partly decayed, and appears in the later stages of the colonisation by *Ips longifolia* or *Polygraphus major* (Stebbing, 1914, p. 520, as nigra Stebb.). **P. bassiae** in *Bassia latifolia* in south India. **P. burmanicus** in *Pinus khasya* in Burma.

Polygraphus longifolia

Restricted to *Pinus longifolia* in the Himalayas and Siwaliks. The beetle, 2·7–3 mm., has the declivity tuberculate in the male (less so than in *P. pini*) and the front of the female head with a brush of hairs. The larva, 2·5 mm., is described by Gardner, 1934, p. 11, fig. 32.

Life-history: The gallery-system is polygamous and consists of a small pairing-place, 2 to 4 fairly straight mother-galleries running axially (longitudinally) for 2 or 3 inches mainly in the bark-stratum and each having a few aeration-holes. The egg-niches and the larval galleries and pupal cells are almost entirely in the bast-stratum, consequently the sapwood surface from which the bark has been stripped shows only the tracks of the mother-galleries. In small branchlets the pupal cells are slightly sunk in the wood.

There are 3 or 4 generations a year at a quick rate of development in fresh breeding-material. Nevertheless logs or branches or twigs, which are attacked early in the year, continue to produce beetles throughout the following 12 months. At Dehra Dun, 2,200 feet, the main emergence-period is August, September, and decreasing numbers of beetles appear throughout the winter, spring and hot weather from the same caged material; the later population is composed of slowly maturing individuals. At higher elevations the insects are inactive and hibernate during the winter.

Economic importance; Although development is protracted and successfully completed in dried-out bark, which may be occupied for over a year, *P. longifolia* does not readily attack anything but newly killed trees. Fellings and windfalls are preferred. Pine saplings and poles scorched by ground-fires are

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Fig. 113. Pinhole and shothole borers.

No. 1—*Webbia pabo*, female, natural size 2 mm.

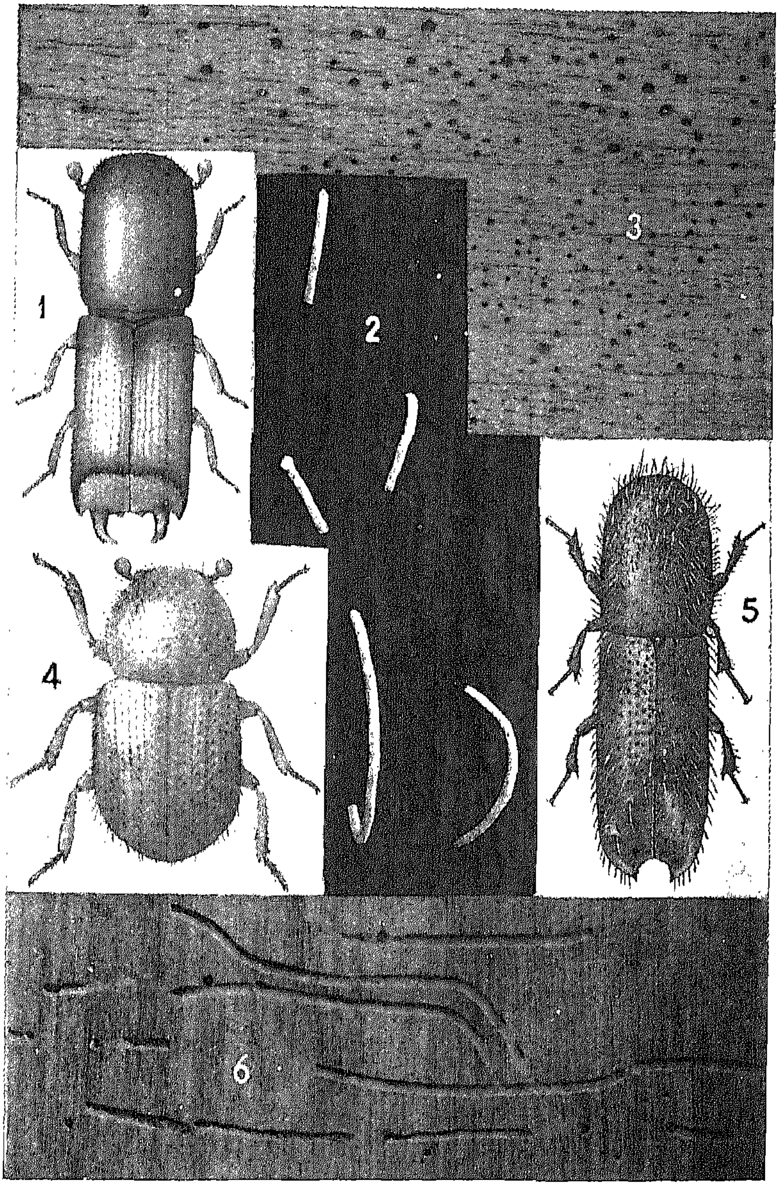
No. 2—Frass ejected in solid cylinders from the entrance-holes of the galleries of *Xyleborus semigranosus* in *Cinnamomum camphora*, natural size.

No. 3—Surface of plank of *Sterculia campanulata* showing pinholes of several species of *Xyleborus* and *Webbia*, natural size.

No. 4—*Xyleborus semigranosus*, male, natural size 1·7 mm.

No. 5—*Xyleborus shoreae*, female, natural size, 3·1 mm.

No. 6—Sapwood surface of *Terminalia procera* showing link-galleries of *Xyleborus incurvus*, natural size.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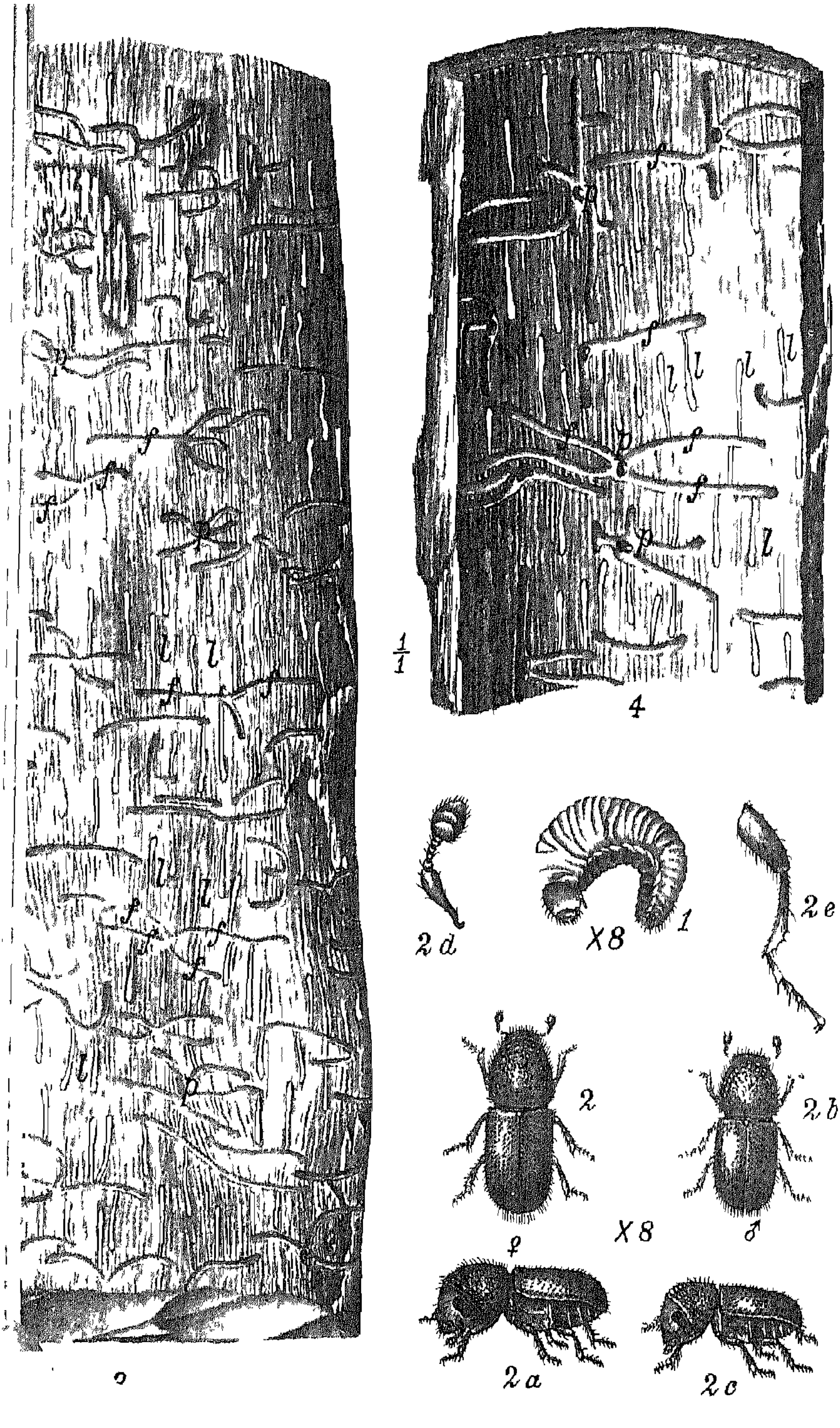
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liable to attack in the lower branches and boles. Pine trees killed by fierce forest fires are not particularly susceptible to attack and epidemics of *P. longifolia* do not arise from this cause.

Gardner, 1934, *Ind. For. Rec.*, xx, viii, pp. 11, 12, fig. 32 (larva).
Stebbing, 1914, *Ind. For. Ins.*, pp. 524, 527, pl. li, fig. 339 (biology).

Polygraphus major

Cedrus deodara, *Picea morinda*, *Pinus excelsa*, ascending to 9,000 feet in the Himalayas. The beetle, 2·8–3·8 mm., has a covering of fine dusty scales; the front of female head is flattened and concealed by long dense yellow hairs. [fig. 4, No. 53].

Life-history: The gallery-system is polygamous with 3 to 5 curved mother-galleries 1–2 inches long and a spacious pairing-chamber which deeply channel the sapwood-surface.

Egg-niches (to about 15 per gallery) form shallow pits in the wood but the larval galleries run for ¾–1 inch almost completely in the bast-stratum and leave little or no track on the cambium-surface. The pupal cells, on the contrary, are bored out to full length in the sapwood in which their mouths appear as circular holes. An attacked branch stripped of its bark shows on the wood a whorl of nicked egg-tunnels and disconnected lines of pits.

The life-cycle at about 6,000 feet takes 7 to 10 weeks and allows a sequence of 4 generations a year. But the rate of development of a brood is very variable and the life-cycle may be prolonged to extend over the winter and last for nearly a year. Spring emergence begins in April but infested material may yield beetles throughout the active season.

Economic importance: *P. major* breeds chiefly in small branches and stems, the bark of which is thin and unsuberised; and particularly in *Pinus excelsa*. It does not occur in large poles and trunks with thickened bark. At the time of attack the bark is usually quite green and full of resin and though resin may trickle from cracks in the bark and solidify in a ring round the entrance-hole, the interior of the gallery is not contaminated. This *Polygraphus* is able to establish its mother-galleries in young healthy living trees by localised mass-attacks; there must be a damaged or unresistant plant present to attract the swarms of beetles in the first instance and to focus the mass-attacks on closely adjacent plants, as in patches of regeneration or groups of young poles. Outbreaks of this nature may occur after fellings, snow-break and snow-pressure, windfalls, lightning stroke, etc.

For Control see Part Two, Scolytidae.

Fig. 114. Dryocoetes hewetti, a polygamous bark-beetle. Nos. 1 and 2—Larva and beetle (antenna and leg) of *Dryocoetes hewetti*. Nos. 3 and 4—*Quercus incana*, sapwood surface, 3, and inner surface of bark, 4, showing mother-galleries, f, pairing-chamber, p, and larval galleries, l, of *Dryocoetes hewetti;* one half natural size.

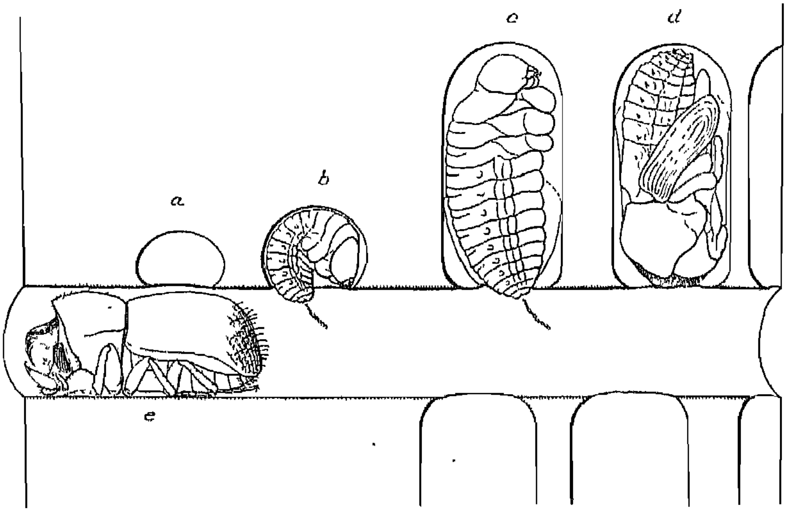

Fig. 115. Part of gallery-system of Scolytoplatypus pubescens seen in longitudinal section of Amoora wallichii.

(a) egg-niche in first larval stage
(b) early larval cell enlarged by larva
(c) full sized larval cell containing mature larva, with aperture still open for defecation
(d) pupa in cell, with aperture closed and ambrosia-fungus growing in all interstitial spaces
(e) male beetle in the main gallery.

Stebbing, 1914, *Ind. For. Ins.*, pp. 501-510, figs. 328-331, pl. xlvii.

P. melanotus in *Pinus excelsa* at high elevations. **P. pini**, 2·1–2·7 mm., in *Abies webbiana*, *Cedrus deodara*, *Picea morinda*, *Pinus excelsa*. A polygamous species of habits similar to *P. major* and *P. aterrimus* but more subsequent than these species in its attack and breeding in the trunks of trees as well as small branches. It makes 3 to 5 curved and radiating mother-galleries which together with the larval galleries are largely and often entirely in the bast-stratum leaving no trace on the sapwood. **P. setosus**, a small species in branchlets of *Pinus longifolia*. **P. trenchi**, 2·6–3·4 mm., the female of which has a concave frons covered by a fringe of ruddy gold hair. The beetle is polygamous making 2 to 4 straight, 1½–3 inch long, mother-galleries which are longitudinal (axial) and closely parallel. All parts of the gallery-system groove the sapwood and leave on it a pattern similar to that on the inner face of the bark except that the early part of the larval gallery is absent from the sapwood.

Stebbing, 1914, *lit. cit.*, pp. 510-520, fig. 333, pl. xlviii, xlix.

Pseudoxyleborus beesoni, 4·5 mm., a shothole borer of the wood of *Nephelium longana* in Burma.

Ptilopodius ramosus, 1·4 mm., in the bark of *Hibiscus tiliaceus* from Indian coasts to the Pacific islands. [fig. 4, No. 57].

Pseudothamnurgus pilicornis in dying branches of *Euphorbia neriifolia*. **P. royleanus** in *Euphorbia royleana* in India. Larval characters are given by Gardner, 1934, p. 10, figs. 10, 11.

Scolytogenes major, 2·5 mm., in *Cryptolepis buchanani* in India.

Scolytomimus insularis in *Mimusops lateralis* in the Andamans.

In the shothole-borer genus **Scolytoplatypus** the beetle has some features in common with Platypodidae, i. e., a similar pronotum leaving the head mobile and free at the sides, [fig. 115] and other similarities in the antennal club, pronotal pore, etc. but the larva [fig. 112, No. 8] has none of the peculiarities of the platypodid larva. The gallery system is of the same type as in *Trypodendron* [fig. 109]. The parent beetle drills an entrance-tunnel into the sapwood and continues the main gallery parallel to the circumference in a transverse plane; minor branches are added. Eggs are deposited in rows of pits on the 'floor' and the 'ceiling' of the mother-gallery [fig. 115, *a*]. An ambrosia-fungus grows on the walls of the galleries and extends into the intersected vessels quickly staining them black. On hatching from the egg which is embedded in its pit the larva gnaws at the surrounding wood and prepares a cell for itself [fig. 115, *b*]; and as the larva grows in size it continues to enlarge its cell by scraping away the wood-tissue and swallowing it. The cell of a young larva is spherical to oval: that of an old larva is cylindrical with concave ends [fig. 115, *c*]. Ambrosia-fungus grows in the wood all round the larval cell and spreads in a thick layer within the cell; it is constantly browsed back by the larva which can move in any direction, doubled up in a **U** [fig. 112, No. 8]. The mouth of the cell opening into the mother-gallery is plugged with a thick wad of fungus, except for a circular hole through which the tip of the abdomen of the larva is protruded. [fig. 115, *c*]. The larva defecates an almost continuous string of pellets which remain adherent although dryish; excrement containing more undigested wood than digested fungus is yellowish and mottled. It is the work of the male beetle [fig. 115, *e*] to remove the excrement from the rows of larval cells and to keep the galleries clean. After the larva has pupated the fungus grows around the pupa while it is quiescent, filling all the interstices [fig. 115, *d*]; the immature beetle eats this accumulation of food and widens the aperture before escaping from the cell. When the brood swarms both males and females leave by the original entrance-hole and disperse.

Scolytoplatypus brahma, 3-4 mm., a shothole borer of *Ilex dipyrena*, *Swietenia mahagoni* in Assam-Bengal. **S. darjeelingi**,

2·8–3 mm., in *Alnus nepalensis, Eucalyptus globulus, Litsaea elongata, L. umbrosa, Prunus nepalensis, Quercus lamellosa, Symplocos theaefolia.* **S. discicollis** in *Symplocos theaefolia.* **S. kunala**, 4 mm., in *Abies pindrow, Acer caesium, Cedrus deodara, Hedera helix, Parrottia jacquemontiana, Picea morinda, Prunus padus, Pyrus lanata, Quercus dilatata, Q. incana, Q. semecarpifolia, Taxus baccata.* **S. lepcha** in *Evodia fraxinifolia, Symplocos theaefolia.* **S. minimus**, 1·5–2 mm., *Alnus nitida, Cornus macrophylla, Prunus armeniaca.*

Scolytoplatypus pubescens, 4–5 mm. in *Acer campbelli, Alnus nepalensis, Amoora wallichii, Engelhardtia spicata, Evodia fraxinifolia, Litsaea elongata, Prunus nepalensis, Quercus incana.* The life-history is summarised in the paragraph on the genus; the gallery-system of one brood of about 70–80 individuals is shown dissected in fig. 109; the larval cells and beetle are shown in fig. 115, *a*-*e*. The larva, 5 mm., is shown in fig. 112, No. 8, and is described in 1934, *Ind. For. Rec.*, XX, viii, pp. 4, 5, figs. 7–10.

Scolytoplatypus raja, 3–4 mm., *Abies webbiana, Acacia decurrens* (in Malaya), *Cedrus deodara, Cornus macrophylla, Engelhardtia spicata, Litsaea elongata, Macaranga denticulata, Machilus odoratissima, Picea morinda, Prunus nepalensis, Quercus incana, Q. lamellosa, Symplocos theaefolia* in the Himalayas. Stebbing, 1914, *Ind. For. Ins.*, pp. 604–606, figs. 384, 385, pl. lxi (as himalayensis). **S. siva** in *Engelhardtia spicata.*

Scolytus chelogaster in *Ulmus lancifolia* in Assam. **S. himalulmi** in *Ulmus wallichiana* in Kashmir. **S. juglandis** in *Juglans regia, Pyrus lanata, P. malus, Prunus armeniaca*; the axial monogamous mother-gallery and very long larval galleries are engraved deep in the sapwood. **S. kashmirensis** in *Ulmus wallichiana.*

Scolytus major

In *Cedrus deodara* throughout its range. The beetle, 2·5–4·5 mm., is black with a tubercle in the middle of the forehead and without armature on the abdomen. The larva, 5 mm., is described in Gardner, 1934, p. 6, figs. 11–13.

Life-history: The gallery-system comprises an oblique entrance-tunnel starting under the concealment of a flake of bark and leading into the lower end of a single axial mother-gallery, which is strongly sinuous for the whole of its 2 or 3 inches of length and is engraved about 1/3rd of its depth in the sapwood. About 50–80 eggs are laid in marginal egg-niches. The larval galleries run contiguously at first but are more sinuous in their latter parts and end in pupal cells pitted in the wood. The whole gallery-pattern is clearly impressed on the sapwood-surface and also shows on the inner surface of the bark. [fig. 110]. There are 4 generations a year at a quick rate of development, the shortest life-cycle taking about $2\frac{1}{2}$ months. But broods and individuals

of all generations vary considerably in the time taken to reach maturity and in consequence the emergence of beetles from infested logs may be protracted for the full year.

Economic importance: *S. major* can breed in tree-trunks of large dimensions, [fig. 110] poles, small branches and twigs. Thick-barked material affords the best environment; in thin-barked branches where nourishment is deficient the brood-patterns are small and the resulting beetles are under average size. In branchlets or twigs the mother-gallery is a short spiral or a ring which almost severs the twig. It normally breeds in killed or fallen trees and readily attacks sickly or injured standing trees, but whether it establishes itself in the latter depends on the individual tree's power of resistance and the abundance of the attacking swarms. An unhealthy tree may produce enough resin to check the attack in the early stages of oviposition. *S. major* is usually a later arrival than species of *Pityophthorus* and under these circumstances its appearance is symptomatic that the deodar is unhealthy. The attack is not primary but it may hasten the death of the tree. Primary attacks by *S. major* can take place when excessive multiplication has occurred in felling-refuse on clear-felled areas; the advance-growth and young pole woods are particularly susceptible. Small deodar may be killed by mass-attacks; the leading and lateral shoots may be pruned off, or some of the branches may be girdled by the encircling mother-galleries. Damage of this nature is localised to compartments where recent fellings have been made, and is done by the monsoon and post-monsoon broods.

Gardner J. C. M., 1934, *Ind. For. Rec.*, XX, viii, p, 6, figs. 11-13 (larva).
Stebbing E. P., 1914, *Ind. For. Ins.*, pp. 568-582, figs. 360-365. pls. lvii, lviii (coloured), lix, frontispiece (coloured)-as Scolytus deodara, major and minor; biology and previous references.

The genus **Sphaerotrypes** comprises barkbeetles that are hemispherical to hemiovular, the dorsolateral area being strongly convex and scaley [fig. 117]. The larva is also stout and broadly oval, 3 mm. long by 2 mm. wide and nearly 2 mm. thick. [fig. 116, No. 1]. The gallery-pattern is an axial monogamous mother-gallery grooving the sapwood with larval galleries extending to the circumference of a circle or oval which is traced on the outer bark by a ring of exit-holes: sometimes the exit-holes are close and continuous so that a disc of bark is cut free.

Beeson, 1921, *Ind. For.*, XLVII, pp. 514-518, Barkbeetles of the genus Sphaerotrypes.

Sphaerotrypes coimbatorensis, 2·5–3 mm., in *Anogeissus latifolia* in south India. **S. dulcispei** in *Hopea parviflora* in south India. **S. globulus**, 2·6–3·2 mm., in *Anogeissus latifolia*, *Lagerstroemia parviflora*, *Terminalia tomentosa*. **S. pentacme** in *Pentacme suavis* in Burma. **S. quadrituberculatus** [fig. 117] 3–3·3 mm., in *Drimycarpus racemosus*. **S. querci**. 3 mm., in

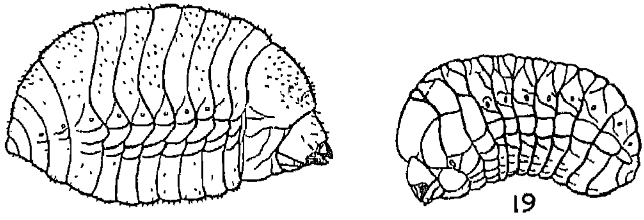

Fig. 116. No. 1, larva of Sphaerotrypes siwalikensis, natural size 3 mm.; No. 19, larva of Hyorrhynchus, natural size 6 mm.

Quercus dilatata. **S. rufopalliatus,** 2·1 mm., in *Shorea parvifolia* in Malaya.

Sphaerotrypes siwalikensis

In *Shorea assamica* and *Shorea robusta* throughout its habitat. The beetle, 2·8–3·5 mm., is more strongly tuberculate than its allies [fig. 117]; the larva, 3 mm., is shown in fig. 116. (Gardner, 1934, p 5, figs. 1–3). The gallery-pattern consists of the normal axial single mother-gallery, 1 to 2 inches long, with a sheaf or oval of as many as 80 larval galleries and terminal pupal cells, all slightly engraved in the sapwood and so making similar impressions on the surfaces of bark and wood; the larvae leave a greyish fine dust.

Life-history; The insect is active throughout the year in Central India but has a prolonged hibernating generation in north India (U. P.), where the general spring emergence does not begin till mid-February. There is no definite series of generations as overlapping broods in all stages occur at any time during the season of activity; but two main swarming-periods occur in north India, March–May and August–October.

The shortest life-cycle of the individual from egg to emergence is 6 or 7 weeks in May–July, and longer for broods starting at the end of February or in September; broods which begin to emerge in October in north India continue to mature until April of the following year. The emergence-period of a brood is as long as or longer than the period of its shortest life-cycle, and it gives a fairly symmetrical graph with a peak midway, e.g., minimum life-cycle 8 weeks, maximum about 4 months, emergence-period about 3 months. A log or branchwood with a mixed infestation may yield beetles for 8 months (over winter).

Economic importance: *S. siwalikensis* was formerly considered a serious primary pest of *Shorea robusta* capable of killing small poles and of hastening the death of large moribund trees (Stebbing, 1914). It is certainly a common secondary bark-borer of sal throughout its range and establishes its broods in fresh moist bark in any space left untenanted by other borers. It

multiplies abundantly wherever there are regular fellings, and, after the custom of most bark-beetles, attacks and attempts to bore its tunnels in living healthy trees when other more suitable breeding-material is no longer available; but if these attempts fail the beetle is gummed up in the entrance-tunnel by the flow of damar which a vigorous tree can produce. Epidemics of *Hoplocerambyx spinicornis* or *Polyporus shoreae* have nowhere been followed by killing of healthy sal trees by *siwalikensis.*

It is able to establish successfully in the crowns of stag-headed trees but does not extend to the bole until the latter begins to die. *S. siwalikensis* provides useful indications of the physiological conditions prevailing in the tree at the time of its dying. If the attacked bark is relatively vigorous and resistant the bore-hole is at once filled with resin and the beetle is driven out or entombed. If the bark dries rapidly the beetle is able to oviposit but the brood fails to develop further. Intermediate conditions permit correspondingly more successful or complete development of the borer. (Beeson, 1934).

LITERATURE:

Beeson, 1915, *Ind. For.*, pp. 296, 297; 1921, *tit. cit.*, p. 515 (synonomy).
— 1934, *tit. cit.*, pp. 539-543, The role of insects in the dying off of sal.
Gardner, 1934 *Ind. For. Rec.*, XX, viii, pp. 5, 6, figs. 1-3 (larva).
Stebbing, 1914, *Ind. For. Ins.*, pp. 476-490, figs. 314-321, pls. xiii, xliv (as Sphaerotrypes assamensis, globulus and siwalikensis; illustrations of gallery-pattern, etc.).

S. tectus in *Quercus incana.* **S. vateriae** in *Vateria copallifera* in Ceylon. **S. vaticanus** in *Vatica lanceaefolia* in Assam.

Spongotarsus thitsi, 5 mm., in *Melanorrhoea usitata* in Burma.

The genus **Stephanoderes** comprises numerous species of borers of twigs and fruits of trees; the beetles range in size from 1-3 mm. and resemble very closely the beetles of *Hypothenemus.*

Stephanoderes alter, 1·8-2 mm., in *Cynometra ramiflora, Dryobalanops aromatica, Swietenia macrophylla*, Malayan region to Bengal and Ceylon. **S. cassiae**, 1·5 mm., in pods of *Cassia* spp. and dry twigs of *Crotolaria.* **S. cuneolus**, 2·4 mm., in *Dryobalanops aromatica.* **S. glabripennis**, 2·2 mm., in branches of *Tamarindus indica* in the Andamans.

Stephanoderes hampei, The Coffee Berry Borer.

Economic importance: This pest of coffee, *Coffea arabica, C. liberica* and *C. robusta*, is a native of tropical Africa whence it has been introduced into nearly all coffee-growing regions of the world. It was detected in Java about 1908 and then in Brazil about 1913, in Sumatra in 1919, in Malaya about 1929 and in Ceylon in 1935. Imported coffee seeds containing beetles have been intercepted at Indian ports several times since 1930 but the pest is not established in India. It is widespread in Ceylon where it has been prescribed as a pest under the Plant Protection Ordinance.

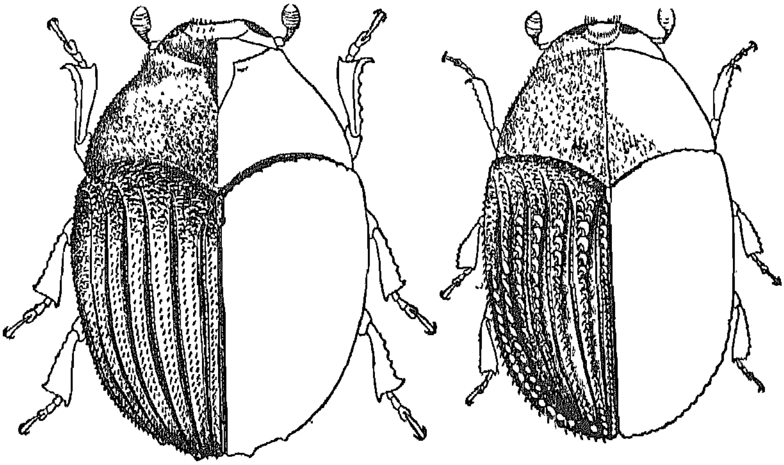

Fig. 117. Beetles of (left) Sphaerotrypes quadrituberculatus, natural size 3–3·3 mm.; (right) Sphaerotrypes siwalikensis, natural size 3–3·5 mm.

Life-history: The female beetle, 1·5–1·9 mm., dark brown with rows of pale stiff bristles, bores into ripe or nearly ripe coffee berries (i.e., in those in which a hard bean has already formed, also if the berry is still green) entering at or near the depression at the apex of the berry. Eggs are laid in a chamber at intervals of a few days and the larvae feed by tunnelling out the beans. In heavy infestations the berry is riddled and reduced to black dust. The average family of one beetle is about 50 but over 160 beetles have been found in one bean.

The life-cycle in Malaya is 31 days and in Ceylon takes about 31 days (egg 6, larva 20, pupa 5 days); and in Java 20–36 days (egg 5–7, larva 10–21, pupa 4–8 days); in Africa 30–60 days. There is an interval of 5–20 days between emergence of the female and oviposition. Female beetles live for as long as 4 months in Africa, 3½ months in Java and over 2 months in Ceylon. The males are much smaller and wingless and form about a tenth of the population. Unripe berries are bored by the female beetles in order to feed but are not suitable for the development of larvae; green attacked berries die and fall off, or one of the beans dies; this source of injury causes various grades of loss in weight and quality of the harvested crops.

LITERATURE:

There is an extensive literature in journals, bulletins, etc. of interested countries in Africa, S. America, Netherlands Indies, etc. dealing with bionomics and control.

Coleman L., 1931, *Dept. Agr., Mysore*, Bull. 16, Report on the coffee borer Stephanoderes hampei in Java.

Anon, 1931, *Mysore Agric. Calendar*, pp. 29, 33, The coffee berry borer, figs. 1-4.

Anon, 1935, *Trop. Agric.*, LXXXV, pp. 318-320, The coffee berry borer.

S. javanus, 1·8 mm., in *Buchanania sessilifolia, Dipterocarpus zeylanicus, Dryobalanops aromatica, Dyera costulata, Mangifera indica, Sterculia macrophylla, Tamarindus indica*, Java to Bengal and Ceylon. **S. nibarani**, 2·3 mm., in branchlets of *Anogeissus latifolia, Mallotus philippinensis, Santalum album*, (1933, *Ind. For. Rec.*, XVII, ix, p. 10, fig). **S. ramulorum** in twigs of *Bauhinia retusa, Ficus bengalensis, Flemingia congesta, Lannea grandis, Mallotus philippinensis, Mangifera indica, Pterospermum acerifolium, Tectona grandis*, in India. **S. uniseriatus**, 1·5 mm., in dry twigs and dry coffee berries in tropical Africa and south India.

Stephanorhopalus inermis, 1·4 mm., in *Rhizophora mucronata.*

The genus **Thamnurgides** comprises numerous species that are borers of fruits and seeds of forest trees and some that are bark-borers; some of the fruit-boring species live in bark during periods when fruits are not freshly available; owing to the variation in the quantity of food available to the larva the range in size of the adult is often within 200 percent. See Beeson, 1939, *Ind. For. Rec.*, Ent., V, No. 3, pp. 279–308, New species and biology of Coccotrypes and Thamnurgides.

Thamnurgides ater, 2·7 mm., in fruits of *Carapa obovata, Dipterocarpus kerrii, Livistona cochinchinensis* and *Myristica cinnamomea* in Malaya. **T. bambusae**, 3·8 mm., in *Bambusa tulda* in Burma. **T. brevipilosus**, 2·3–2·6 mm., in bark of *Bucklandia populnea, Juglans regia* and *Prunus nepalensis.*

Thamnurgides cardamomi, 2·4–2·6 mm., in fruits of *Canarium strictum, Cullenia excelsa, Elaeocarpus tuberculatus, Ellettaria major, Hardwickia pinnata* and *Vateria indica.* This south Indian and Sumatran species is a borer of the fallen fruits of the forest trees cited, entering through the hard shell of the seed after the soft outer parts have decayed or have been destroyed by other organisms. The larvae feed in the embryo of the seed taking very different times to mature and emerging over a period of 6 or more months. Beetles derived from the fruits of trees bore into green fallen cardamom fruits of plants growing in cardamom malees in evergreen forest. Although the insect has obtained the name of the 'Cardamom beetle' and is notorious as a pest in south India, the incidence of attack in cardamom malees is not serious and the species is not responsible for the failure of the crop as has been erroneously assumed. It invades the malees only after the fruit has formed. Larvae do not develop in cardamom berries and beetles do not bore into dried stored cardamoms.

For control, if necessary, see Part Two.

Thamnurgides cinnamomi, 2 mm., in fruits of *Cinnamomum zeylanicum, Machilus macrantha.* **T. corticis**, 1·7–1·9 mm., in bark of *Dalbergia sissoo, Lannea grandis, Pinus longifolia,*

Shorea robusta, *Terminalia tomentosa*. **T. cyperi**, 1·9–2·2 mm., Assam to Samoa, in bark of *Aesculus punduana*, *Amoora wallichii*, *Eugenia formosa*, *Macaranga denticulata*, *Swintonia floribunda*, *Terminalia myriocarpa*, *Xylia dolabriformis*; also occurs as a borer of the fruits of *Eugenia formosa*. **T. dipterocarpi**, 3·4–3·6 mm., in fallen fruits of *Dipterocarpus pilosus*.

T. gedeanus, 2·5–3·5 mm., in fruits of *Balanocarpus heimii*, *Canarium* sp., *Dipterocarpus crinitus*, *Dryobalanops aromatica*, *Garcinia merguensis*, *Shorea maxima*. The female bores into the fallen fruit and deposits eggs at the end of a tunnel; only one brood of 10–20 individuals is raised by one female who remains with it until all are mature. The minimum life-cycle (in Malaya) is 20 days (preoviposition-period 6 days, egg-stage 4, larva 12, pupa 4). The male beetle is small, blind, wingless and does not leave the seed; only 1 percent of the beetles are male.

Browne F. G., 1939, *Malayan For.*, VIII, pp. 107-115, figs. 1-9, The chengal seed-beetle Coccotrypes graniceps Eichh.

T. glandis, 2·3–2·6 mm., in fallen fruits of *Dipterocarpus pilosus*, *Eugenia formosa*, *Mesua ferra*, *Quercus spicata*, *Terminalia myriocarpa*.

T. himalayensis, 2·2–2·4 mm., in bark of *Bucklandia populnea*, *Castanopsis hystrix*, *Juglans regia*, *Lindera pulcherrima*, *Mallotus roxburghianus*, *Turpinia nepalensis*. **T. indicus**, 1·6–3·0 mm., is a borer of the fruits of *Borassus flabellifer*, *Canarium strictum*, *Carallia lucida*, *Coffea arabica*, *Elaeocarpus oblongus*, *Eugenia jambolana*, *Ficus glomerata*, *Gluta travancorica*, and *Vateria indica* and also bores in the bark of various species of trees including *Artocarpus lakoocha*, *Careya arborea*, *Holigarna arnottiana*, *Mangifera indica*, *Swietenia macrophylla*, *Terminalia belerica*, *Xylia dolabriformis*; emerges throughout the year. **T. litoralis**, 2·7–3·1 mm., in fruits of *Heritiera fomes* and in radicles of fallen germinating seedlings of *Rhizophora mucronata* in mangrove forests. **T. masoni**, 2·4–3 mm., in fallen fruits of *Litsaea polyantha*. **T. monoceros**, 3·2–3·9 mm., fruits of *Dipterocarpus pilosus* and *Mesua ferrea*. **T. myristicae**, 2·1–2·5 mm., in fallen fruits of *Myristica fragrans*, the nutmeg tree, after the pericarp and mace have begun to decay. **T. nephelii**, 2·3 mm., in fruits of *Acacia*, *Nephelium* and *Rhizophora mucronata*. **T. opacifrons**, 2–2·2 mm., in bark of *Acrocarpus fraxinifolius*, *Amoora wallichii*, *Artocarpus lakoocha*, *Gmelina arborea*, *Heritiera fomes*, *Terminalia belerica*, *T. myriocarpa*; emerges throughout the year. **T. parvus**, 2–2·2 mm., in the bark of *Acacia pennata*, *Anogeissus acuminata*, *Eugenia jambolana*, *Grewia tiliaefolia*, *G. vestita*, *Lannea grandis*, *Macaranga denticulata*, *Mallotus philippinensis*, *Pinus longifolia*, *Shorea robusta*, *Terminalia tomentosa*. **T. rubidus**, 2·1–2·4 mm., in fallen fruits of *Dipterocarpus pilosus*, *Eugenia formosa*, *Mesua ferrea* in Assam,

Bengal. **T. shanorum**, 2·7–2·8 mm., in bark of *Pinus khasya* in the Shan States.

T. variabilis in fruits of *Cullenia excelsa*, *Dillenia retusa*, *Ficus glomerata*, *Machilus macrantha*, *Myristica cinnamomea*, *Styrax benzoin* and in bark of *Swintonia floribunda*, *Tectona grandis*, South India and Ceylon and Burma to Java. Very variable in size, 1·6–2·3 mm., and in colour, testaceous to black. **T. vateriae**, 1·8 mm., in fruits of *Vateria indica*. **T. vicarius**, 1·5 mm., in fruits of *Eugenia formosa*. **T. vulgaris**, 1·6–1·8 mm., in bark of *Acrocarpus fraxinifolius*, *Aesculus punduana*, *Amoora rohituka*, *Canarium euphyllum*, *Ficus religiosa*, *Phoebe hainesiana*, *Swintonia floribunda*, *Terminalia myriocarpa*. Bengal to New Guinea.

Trogloditica trahax makes an axial monogamous mother-gallery with larval galleries grooving the sapwood and pupal chambers in the bark of *Sindora siamensis*.

Trypodendron intermedius, 3·5 mm. in *Machilus edulis*, *Quercus lamellosa*, *Symplocos theaefolia*. **T. machili** in *Machilus odoratissima* in the Himalayas. The gallery-system of these species of *Trypodendron* is on the same plan as in *Scolytoplatypus* [fig. 109].

Urdugraphus difficilis, a bark-borer of twigs and branches of *Pinus longifolia*. **Vitideres luffae** in stems of *Luffa aegyptiaca*.

The genus **Webbia**, closely allied to *Xyleboricus*, comprises many species of small pinhole-borers making galleries in wood similar to those made by *Xyleborus*.

W. canalifer, 2 mm., in twigs of *Swietenia mahagoni* in Ceylon. **W. obtusispinosus**, 1·9 mm., in *Shorea parvifolia* in Malaya. **W. 18-spinatus**, 2·9 mm., in *Dipterocarpus baudii*. **W. pabo**, 2·1 mm., [fig. 113, No. 1], in *Shorea robusta* in India. **W. talauricus**, 1·9 mm., in *Balanocarpus heimii* and *Shorea leprosula*. **W. 30-spinatus**, 3 mm., with 26 to 30 spines on the circumference of the declivity, is a pinhole borer in *Dipterocarpus pilosus*, *D. tuberculatus*, *D. turbinatus* and *Hopea odorata* in Assam, Burma and the Andamans.

Xyleboricus camphorae, 1·7 mm., a pinhole borer in *Cinnamomum camphora* in Malaya. **X. mediosectus**, 1·6 mm., in *Canarium euphyllum*, *Dipterocarpus pilosus*, *D. turbinatus* and *D. zeylanicus*. **X. medius**, 1·6 mm., in *Canarium euphyllum*, *Diospyros* sp., *Dipterocarpus zeylanicus*, *Hopea odorata*, *Shorea acuminata*, *S. parvifolia*, *Sterculia campanulata* and *S. villosa*. Ceylon to Malaya. The larva of a species of *Xyleboricus* is shown in fig. 120.

The genus **Xyleborus**, the largest in the family Scolytidae, is a collection of hundreds of species of ambrosia-beetles inhabiting all parts of the world where trees grow. A few attempts have been made to sort out the groups of species into subgenera but without practical effect. The size ranges from 1 to 8 mm., and

the shape from cylindrical to hemispherical or globular, and the colour from straw to black. In some species the elytral declivity is truncate, excavate or armed with spines and teeth [fig. 113, No. 5]; in others the pronotum is the largest and most strongly sculptured part of the body.

Life-history: The females of all species are pinhole or shothole-borers in woody tissues or timber. The males do not bore tunnels; in most groups their sole function appears to be mating, their eyes, wings, jaws, thoracic muscles and other organs being atrophied [fig. 113, No. 4]; in a few groups, the pronotum of the male is modified for scraping and scooping and he may carry out the work in colonies which persist for more than one life-cycle in the same gallery-system, but until a male son of this form matures the mother must do the work unaided.

The ambrosia-eating larva [fig. 120, No. 33] is fusiform with a reduced head (as strong mandibular muscles are unnecessary) and a smooth transverse pronotum (as there is no work for a swollen muscular thorax) and sharply dentate mandibles (as these are needed for biting soft tissues). (Gardner, 1934).

The gallery-systems are summarised on page 368 *(a)*, i, ii, iii and *(b)*. A more detailed classification is given by Beeson, 1930, pp. 44–48 (figs. 1–8, 2 pls.). Other examples are illustrated by Browne, 1936. It is not known if the ambrosia-fungus which grows in the galleries is a single species common to all *Xyleborus* or if its identity varies with the food-plant or the host-beetle (compare p. 326). Many species of *Xyleborus* are widely polyphagous, e.g., *testaceus* breeds in over 100 species of trees, and many other ambrosia-beetles inhabit 30 or 40 species of trees; the food-plants of the very polyphagous species are not closely botanically related but those of the oligophagous species are usually generically or tribally allied.

The period during which wood is inhabited by pinhole borers varies from one short life-cycle of 10 days or a fortnight to the other extreme at which colonies continuously breed for over a year before emerging.

Economic importance: Timber that has been attacked by *Xyleborus* shows defects in the form of pinholes or black spots and lines on the sawn surfaces, which spoil it for ornamental purposes and for special uses as matches, veneer, plywood. [Fig. 113, No. 3]. Unless heavily attacked a soft wood is not seriously weakened for structural purposes. Out of the 140 species of *Xyleborus* listed in the following pages, the most important economically are those which the forest officer makes important by accumulating felling-refuse in which they can multiply; the polyphagous species have the best chances of rapidly becoming injurious under such conditions.

A relatively small number of species attack living trees in the

seedling or young sapling stages and such attacks are fatal. Only one species, the shothole borer of tea, persistently breeds in the living plant without killing it.

LITERATURE :

Beeson, 1930, *Ind. For. Rec.*, XIV, x, pp. 209-272, figs. 1-8, 2 pls., The biology of the genus Xyleborus with more new species.

Browne, F. G., 1936, *Malayan For.*, pp. 120-127, figs. 1-5, 1938, *tit. cit.*, pp. 23-30, Biological notes on Malayan Scolytidae.

Eggers H , 1930, *Ind. For. Rec.*, XIV, ix, pp. 177-208, Neue Xyleborus-arten aus Indien.

Xyleborus abruptus in *Styrax benzoin* in Malaya. **agnatus,** 2·6 mm., in poles of *Shorea bracteolata*; the gallery-system is irregularly branched with small communal chambers (Browne, 1938). **alpha** in *Albizzia moluccana*, *Chrysophyllum roxburghii*, *Cordia grandis*, *Quercus serrata*, *Shorea assamica*, *S. robusta*, *Vatica lanceaefolia*. **andamanensis,** 3 mm., in *Artocarpus chaplasha*, *Bombax insigne*, *Pterocarpus dalbergioides*. **amphicranoides** in *Artocarpus kunstleri;* the main gallery carries axial or radial communal chambers as in *shoreae*. **amphicranulus,** 2·2 mm., in *Fagraea gigantea*. **andrewesi,** 2 mm., in *Albizzia lebbek*, *A. stipulata*, *Anacardium occidentale*, *Bombax malabaricum*, *Buchanania latifolia*, *Canarium euphyllum*, *Dillenia pentagyna*, *Dipterocarpus turbinatus*, *Eugenia jambolana*, *Garuga pinnata*, *Lannea grandis*, *Mangifera indica*, *Mesua ferrea*, *Myristica andamanica*, *Parkia speciosa*, *Poinciana elata*, *Shorea robusta*, *S. talura*, *Sterculia alata*, *Tectona grandis*, *Terminalia bialata*, *T. procera*. India to Malaya. The emergence-period may be prolonged over 5 months. (Beeson, 1930). **apertus,** 2·5 mm., in *Shorea leprosula*. **arquatus,** in twigs of *Berberis nepalensis* and *Cinnamomum camphora*, in Ceylon. **artestriatus** in *Prunus puddum* in Burma. **asperatus** in *Acacia decurrens*, *Albizzia moluccana*, *Grevillea robusta*, in Ceylon. **asperipennis,** 2·6-3 mm., in *Acer campbelli*, *Casearia glomerata*, *Eurya japonica*, *Gmelina arborea*, *Leucosceptrum canum*, *Macaranga denticulata*, *Machilus odoratissima*, *Quercus glauca*, *Terminalia myriocarpa* in Assam-Burma. **aspersus** in *Eugenia* sp., in Malaya.

X. badius in *Artocarpus integrifolia*, *Cocos nucifera*, *Ficus* spp., and *Ochanostachys amentacea* in Ceylon and Malaya—a subspecies of *X. torquatus* extending as far as the Fiji Islands. **bicolor** in *Albizzia moluccana*, *Castanopsis tribuloides*, *Duabanga sonneratioides*, *Eugenia jambolana*, *Heritiera fomes*, *Isonandra polyantha*, *Lindera latifolia*, *Myristica andamanica*, *Nyssa sessiliflora*, *Shorea robusta*, *Terminalia belerica* in India and Burma. **bidentatus** *(Progenius)* in *Canarium euphyllum*, *Dipterocarpus turbinatus*, *Mimusops littoralis*, and *Pterocarpus dalbergioides* in the Andamans. **birmanus,** 3·5 mm., in *Dolichandrone stipulata*, *Xylia dolabriformis*. **brevidentatatus** *(Progenius)*, 3·5 mm., in *Pterocarpus dalbergioides*, *Terminalia bialata*, in the Andamans. **burmanicus,** 2·8 mm., in *Adina*

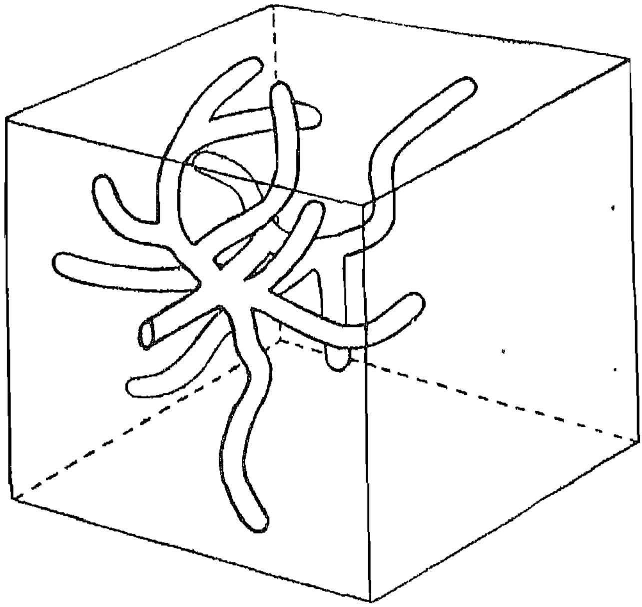

Fig. 118. Gallery-system of Xyleborus butamali shown as an isometric transparency in a block of *Dillenia pentagyna*; numerous branches arise from the main mother-gallery and penetrate for 1 or 2 inches in any direction; natural size.

cordifolia, *Cordia grandis*, *Diospyros ehretioides*, *Dolichandrone stipulata*, *Ficus glomerata*, *Garuga pinnata*, *Macaranga denticulata*, *Tectona grandis*, *Vitex peduncularis* in Burma. **butamali,** 5·1 mm., in *Dillenia pentagyna*, *Terminalia tomentosa* in south India. Gallery-system is shown in fig. 118 as an isometric transparency.

X. chrysophylli, 2·3 mm., in *Chrysophyllum roxburghii* in Assam. **citri,** 2·3 mm., in *Citrus aurantium*, in Bengal. **cognatus,** 2·6–2·8 mm., in *Bombax insigne*, *Bruguiera parviflora*, *Canarium euphyllum*, *Diospyros oocarpa*, *Dipterocarpus turbinatus*, *Exaecaria agallocha*, *Heritiera fomes*, *Lagerstroemia hypoleuca*, *Mimusops litoralis*, *Planchonia andamanica*, *Parishia insignis*, *Pterocarpus dalbergioides*, *Rhizophora mucronata*, *Sterculia alata*, *S. campanulata*, *Terminalia bialata*, *T. procera*, in the Sundarbans to Malaya commonly in coastal forests. The gallery-system is in a transverse plane as shown in fig. 119. (see Beeson, 1930). **comptus** in *Hevea braziliensis* in Ceylon. **concinnus,** 2·1 mm., in *Albizzia moluccana*, in Burma. **corporaali,** 2·7 mm., in *Shorea leprosula*; an expanded communal chamber lies in the transverse plane at the bifurcation of the main gallery. (Browne,

1936). **corpulentus**, 2·8 mm., in *Acrocarpus fraxinifolius*, *Albizzia lebbek*, *Artocarpus chaplasha*, *Canarium euphyllum*, *Sterculia villosa*, *Vatica lanceaefolia*, in Assam-Andamans. **cristatus** in *Alnus nepalensis*, *Quercus lamellosa*, *Symplocos theaefolia*, in Bengal.

X. dalbergiae, 3·4 mm., in *Dalbergia assamica*. **decipiens** in *Balanocarpus heimii*, *Canarium patentinervium*, *Dryobalanops aromatica*, *Santiria griffithi*, in Malaya. **declivigranulatus**, 2·1 mm., in *Adina rubescens*, *Dipterocarpus baudii*, *Xanthophyllum affine*, in Malaya. **dentatus** in *Gordonia zeylanica* in Ceylon. **difficilis**, 1·7 mm., in *Gmelina arborea*, in Assam. **dihingensis**, 5·5 mm., in *Artocarpus lakoocha*, *Phoebe lanceolata*, in Assam. **discolor**, 1·8-2·1 mm., a twig-borer in India–Java of *Albizzia moluccana*, *Cassia multijuga*, *Cedrela toona*, *Ficus glomerata*, *Grevillea robusta*, *Juglans regia*, *Lonicera caprifolium*, *Machilus odoratissima*, *Mallotus philippinensis*, *Mangifera indica*, *Mesua ferrea*, *Pongamia glabra*, *Swietenia mahagoni*, *Tephrosia candida*, *Terminalia myriocarpa*. The gallery is necessarily a short ring, unbranched except for short expansions or vertical bays which house a small brood of about 10. Thick ambrosia is produced which nourishes the larva most effectively and permits it to mature to a beetle within a week, although its size is very variable (see Beeson, 1930). The larva, 4 mm., is described by Gardner, 1934, p. 16, fig. 37. **diversicolor**, 1·5 mm, in *Dipterocarpus baudii*, *Endospermum malaccense*, *Koompassia excelsa*, in Malaya. The gallery-system branches in all planes and 2 or more systems may coalesce. **dorsosulcatus**, 3·2 mm., in *Pentacme suavis* in Burma.

X eggersi, 3·2 mm., in *Litsaea umbrosa*, *Symplocos theaefolia* and *Turpinia nepalensis* in Bengal. **elegans** in *Eugenia jambolana*, *Shorea robusta* in India. **emarginatus** in *Balanocarpus heimii*, *Dipterocarpus baudii*, *Fagraea gigantea*, *Koompassia excelsa*, *Shorea leprosula* in Malaya. **eugeniae**, 2·8 mm., in *Eugenia jambolana* in north India; the larva, 3 mm., is described by Gardner, 1934, pp. 16, 17, fig. 33 [fig. 120, No. 33]. **exiguus**, 1·7 mm., Tenasserim to New Guinea, breeds in *Artocarpus chaplasha*, *Canarium euphyllum*, *Dipterocarpus turbinatus*, *Parkia speciosa*, *Pterocarpus marsupium*, *Terminalia bialata*.

X. fallax, 3 mm., in *Castanopsis tribuloides*, *Dipterocarpus pilosus*, *Koompassia excelsa*, *Shorea leprosula*, *Swintonia floribunda*, *Xylia dolabriformis*, Assam to New Guinea. **fischeri**, 4 mm., in *Sarcocephalus cordatus*, Burma to Sumatra. **foersteri** in *Canarium* sp., *Canthium didymum*, *Pithecolobium bubalinum* in Malaya.

Xyleborus fornicatus

This species, 2·4–2·5 mm., black with the basal third of the elytra flat and horizontal, occurs throughout the India-Malaya region from Ceylon to Java as a borer of twigs and small branches of

numerous species of trees of which 36 species are listed by Beeson, 1930, pp. 58-60; besides forest trees the food-plants include most of the trees used for shade or ornament in tea gardens and also *Ricinus communis*, the woody stem of which is readily attacked when the plant is injured or weakened; the castor oil plant is probably the principal food-plant of *X. fornicatus*. Speyer, 1918 and 1923, lists the food-plants in Ceylon. In thin branchlets the entrance-tunnel, of about 1·3 mm. diameter, turns obliquely inwards and bifurcates into recurved mother-galleries on reaching the other side. Connected with these are two vertical shafts in the pith one running upwards and the other downwards; in very thin twigs these vertical shafts are the only ones that can be made. In larger branchwood of trees or in thick stems of the castor oil plant the mother-gallery is an encircling or circumferential ring as is normal for the group to which *fornicatus* belongs; the galleries are often very closely crowded together.

Life-cycle: Eggs are deposited in lots of 5 or 6 up to a total of 30 in the main galleries; the larva is about 3·5 mm. long when fullgrown (Gardner, 1934); a brood produces on an average 20 percent males. The life-cycle lasts about 6 weeks; in Ceylon there is no well-marked seasonal activity, beetles appearing throughout the year. The emergence-period of broods living in castor in north India may extend over 4 months.

Shothole Borer of Tea: Under certain conditions *X. fornicatus* attacks living tea bushes boring the shoots so that they are killed or break off in the wind or by the passing of garden-coolies. In Ceylon, where it has been a serious problem since about 1890, it is known as the Shothole Borer of Tea and was declared a pest under the Plant Protection Ordnance in 1924. Generations which breed continuously in tea bushes in Ceylon differ morphologically from the typical castor form by their smaller size (2·2-2·3 mm.) and by the elytral curve which is more convex from scutellum to sutural apex; the subspecific name **fornicatior** is given to this Ceylon race. This form appears to be a true biological race conditioned by the food and environment imposed by the tea plant in the Ceylonese climate and soils; tea plantations of some districts in which castor is heavily infested by *fornicatus* are entirely free from *fornicatior*, which becomes uncommon in tea above 4,500 ft. In south India tea is less regularly attacked by shothole borer and only a small proportion of the population bred in tea acquires the *fornicatior* characters; the subspecies is not stabilised. In northeast and northwest India and in Indo-China the tea bush is rarely attacked by *fornicatus*, although the borer is abundant in other hosts in the same locality, and there is no trace of the *fornicatior* characters.

For control measures see Part Two, Scolytidae, Xyleborus.

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X. glabratus, 2·5 mm., in *Lindera latifolia*, *Litsaea elongata*, *Shorea robusta* in Assam, Bengal. **granifer** in *Eugenia* sp., *Myristica* sp. in Malaya. **granulifer**, 1·7 mm., in *Koompassia excelsa*. **granulipennis**, 3·2 mm., in *Ixora parviflora*, *Xylia dolabriformis* in Madras. **gravelyi** in *Symplocos theaefolia* in Bengal. **gravidus** in *Buchanania latifolia*, *B. sessilifolia*, *Cinnamomum cecidodaphne*, *Dehaasia cuneata*, *Mesua ferrea*, *Shorea bracteolata*, *Swietenia macrophylla*, *S. mahagoni*, *Tectona grandis*, *Vatica lanceaefolia* in Bengal-Malaya.

X. haberkorni in *Albizzia moluccana*, *Eugenia jambolana*, *Mangifera indica*, *Salix tetrasperma*, *Shorea robusta*, *Terminalia myriocarpa* in the Indian region. **hagedorni**, 3·4 mm., in *Evodia fraxinifolia*, *Symplocos theaefolia*, in Bengal. **hirtuosus**, 3·8 mm., in *Beilschmiedia sikkimensis*, *Symplocos theaefolia* in Bengal.

X. improbus, 3 mm., in *Eucalyptus globulus*, *Machilus odoratissima*, *Quercus lamellosa*. **improcerus** in *Dipterocarpus cornutus*, in Malaya. **inarmatus** in *Quercus lamellosa* in Bengal. **incurvus**, 2·5–2·9 mm., in *Acrocarpus fraxinifolius*, *Albizzia lebbek*, *Amoora wallichii*, *Artocarpus chaplasha*, *Canarium euphyllum*, *Dipterocarpus turbinatus*, *Cinchona*, *Phoenix paludosa*, *Pterocarpus dalbergioides*, *Nipa fruticans*, *Tectona grandis*, *Terminalia bialata*, *T. procera*. In addition to branched main galleries inside the sapwood this species makes-link-galleries on the surface of the sapwood half in the wood and half in the bark [fig. 113, No. 6] (Beeson, 1930, p. 62, pl.). **indicus**, 2–2·2 mm., in *Artocarpus integrifolia*, *Diospyros pyrrhocarpa*, *Endospermum malaccense*, *Gmelina arborea*, *Koompassia malaccensis*, *Sterculia alata*. Bengal to New Guinea. **infans** in *Balanocarpus heimii*, *Shorea leprosula*.

X. interjectus. This species is the largest common shothole-borer in the forests of India and Burma; it occurs from Japan to the Malay Archipelago. The beetle is 3·4–3·7 mm.; large individuals are more characteristic in regions of high rainfall. It is primarily a borer of softwoods but also rears broods successfully in timbers with a hard heartwood; over 60 species of Indo-Malayan trees are attacked of which 41 are listed in Beeson, 1930, p. 63 and fig. 2. The gallery-pattern is a simple branched main

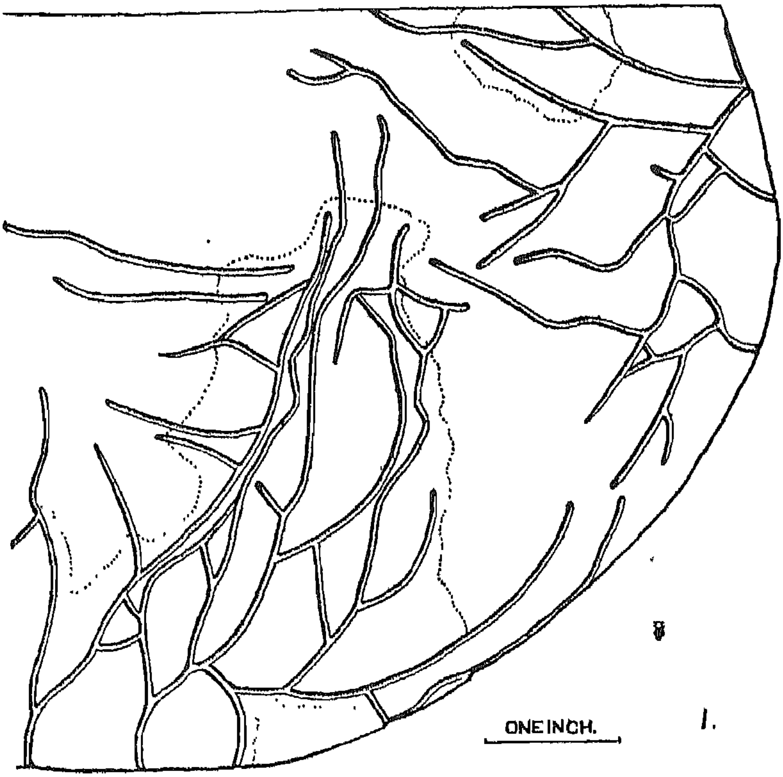

Fig. 119. Gallery-system of Xyleborus cognatus in transverse section of Rhizophora mucronata; the dotted lines enclose areas of rotten wood.

tunnel which rings or partially encircles the sapwood of a small pole and runs with many short branches directly to the heart of large logs. Colonies inhabit the wood for long periods emerging over the greater part of the year but most numerously in March, April. **intextus**, 2·5 mm., in *Acrocarpus fraxinifolius*, *Adina cordifolia*, *Artocarpus lakoocha*, *Casearia glomerata*, *Cinnamomum cecidodaphne*, *Dalbergia assamica*, *D. cultrata*, *Dipterocarpus pilosus*, *Dolichandrone stipulata*, *Garuga pinnata*, *Gmelina arborea*, *Ostodes paniculata*, *Phoebe hainesiana*, *Sapium eugeniaefolium*, *Shorea assamica*, *Tectona grandis*, *Tetrameles nudiflora*, *Xylia dolabriformis*, in Assam-Burma.

kraatzi see **testaceus**.

X. lantanae in *Albizzia lebbek*, *Anogeissus acuminata*, *Gmelina arborea*, *Mangifera indica*, *Michelia champaca*, *Lantana aculeata* in India. **latecarinatus**, 2·4 mm., in *Shorea scutulata*.

laticollis, 2·7 mm., in *Eugenia jambolana, Heritiera fomes, Lannea grandis, Mallotus philippinensis, Phyllanthus emblica, Semecarpus anacardium, Shorea robusta.* In India this species bores into logs stored in the sun within a few months but does not attack those stored in the shade and most of the broods mature within 12 months of the felling date. **leprosulus**, 1·7 mm., in *Shorea leprosula.* **lewekianus**, 4 mm., in *Poinciana elata* in the Nilgiris. **lineatus**, 2·5 mm., in *Machilus edulis* and *Symplocos theaefolia.* **major**, 5·7 mm., [fig. 4, No. 52], in *Dipterocarpus turbinatus, Shorea robusta;* Bengal to Andamans. The gallery-system consists of several short branches from a slightly expanded chamber, the whole being in a transverse plane. **malloti**, 2 mm., in *Mallotus philippinensis.* **mancus** in *Buchanania latifolia, Cordia myxa, Dryobalanops aromatica, D. oblongifolia, Hibiscus macrophyllus, Shorea macroptera, Styrax benzoin, Swietenia macrophylla, S. mahagoni, Theobroma cacao, Vitex pubescens;* E. Africa to Philippines; primarily a borer of small poles and branchwood. There is a main circular mother-gallery with short branches and large irregular chambers which may accomodate a brood of about 30. (Browne, 1938). **marginatus** in *Balanocarpus heimii.* **mascarensis**, 2·2–2·3 mm., in *Acacia melanoxylon, Albizzia* spp., *Ficus* spp., in Ceylon and Malaya. Extends from South America and the Pacific islands to Africa. **melancranis**, 2·7 mm., in *Alnus nepalensis.* **mesuae**, 1·1 mm., in *Mesua ferrea.* **metacomans**, 5 mm., in *Clerodendron infortunatum, Terminalia myriocarpa* in Bengal-Burma; the larva, 7 mm., is described in Gardner, 1934, p. 16, fig. 36. **minor**, 4×2 mm., in *Albizzia procera, Machilus odoratissima, Mallotus philippinensis, Pterospermum acerifolium, Shorea robusta, Tectona grandis, Terminalia tomentosa* in India-Burma; the gallery-system consists of several right and left branches from a main radial entrance-tunnel. The species is strongly gregarious and bores entrance-holes at very short distances from one another so that there is considerable linkage between originally independent brood-tunnels and an intricate network is formed in all planes (compare fig. 118.). *X. minor* does not readily attack freshly felled timber preferring material in shaded places a few weeks dead or already invaded by the mycelium of decay. The large bore and close network of its tunnels causes rapid decay of the outer zones of wood, but the ambrosia-fungus does not stain the adjoining wood conspicuously. Emergence occurs abundantly in April-June but predominantly in May and beetles escape in small numbers throughout the year. The normal cycle of development of the community is thus annual and the extension of the colonies takes place without swarming. (Beeson, 1930).

X. minutissimus, 1·4 mm., in *Albizzia stipulata, Hymenodyctyon excelsum, Lindera latifolia* in Bengal-Malaya. **moestus**, 2·4 mm., in *Quercus lamellosa.* **morigerus** extends from Ceylon

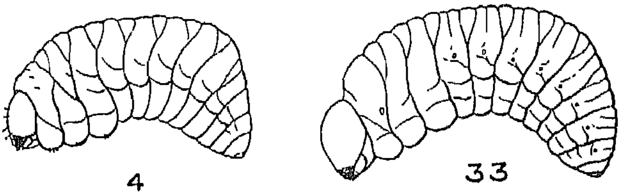

Fig. 120. No. 4—Larva of Xyleboricus, a pinhole borer of Machilus, natural size 2·5 mm. No. 33—Larva of Xyleborus eugeniae, natural size 3 mm.

to Samoa and has been imported to Europe as a borer of orchids; it also bores stems of *Crotolaria anagyroides*, *Leucaena glauca*, *Schleichera trijuga*, *Swietenia mahagoni*, *S. macrophylla*, *Tectona grandis*, *Tephrosia vogelii*, making a short entrance-tunnel into the pith or centre and then runs a shaft upwards and downwards. **morstatti**, 1·8 mm., in *Coffea arabica*, *C. canephora*, *C. robusta*, *C. stenophylla*, *Desmodium ovifolium*, *Hopea parviflora*, *Melia azedarach*, *Persea gratissima*, *Swietenia macrophylla*, *S. mahagoni* from East Africa to Fiji; it attacks living seedlings or trees up to 3 years old and small twigs making holes a millimetre in diameter leading to a circular brood-gallery which has short branches running up and down; the leaves of the seedling wither and the stem dies often breaking off at the girdling gallery (Beeson, 1930). **mucronatulus**, 1·5 mm., in twigs of *Mesua ferrea*. **mus**, 2·2 mm.. in *Gmelina arborea* and *Michelia champaca* in Bengal. **mussooriensis**, 2·5 mm., in *Berberis nepalensis*. **mutilatus** in *Swietenia macrophylla* in Malaya.

X. nepos, 3·3 mm., in *Sterculia alata* in the Andamans. **noxius**, 2·5 mm., [fig. 4, No. 55], is a shothole-borer of about 35 species of the common forest trees in south and central India most of which are listed in Beeson, 1930, p. 75; the gallery-system (*lit. cit.*, fig. 4) is many-branched in a transverse plane and the entrance-holes are connected by short tunnels on the surface of the sapwood. **nugax**, 1·7 mm., in *Dipterocarpus baudii*. **ovalicollis**, 4·6–5 mm., in *Artocarpus lakoocha*, *Casearia glomerata*, *Leucosceptrum canum*, *Macaranga denticulata*, *Symplocos theaefolia*, in Assam-Bengal.

X. peguensis in *Acrocarpus fraxinifolius*, *Xylia dolabriformis*, Bengal. **percorthylus** in *Shorea leprosula*, *S. eximia*; link galleries are made on the surface of the wood. **perdix**, 2·4 mm., in *Adina rubescens*. **perparvus**, 1·7 mm., in *Canarium euphyllum*, *Chrysophyllum roxburghii*, *Dipterocarpus baudii*, *Elateriospermum tapos*, *Pentacme suavis*, *Shorea macroptera*, *S. robusta*, *Swintonia floribunda*, Bengal to Malaya in small poles and branchwood. The galleries are irregularly branched with small chambers. **persimilis** in *Balanocarpus heimii*, *Shorea parvifolia*.

philippinensis in *Artocarpus lakoocha*, in Malaya. **pinicola**, 3·5 mm., in *Pinus khasya*, and *P. massoniana*, Burma to Hongkong. **pseudocomans**, 6 mm., in *Mallotus albus*, *Myristica longifolia*, and *Terminalia myriocarpa*, in Assam. **pseudopilifer**, 6·7 mm., in *Dipterocarpus baudii*, *Dryobalanops aromatica*, *Gmelina arborea*, *Shorea acuminata*, *S. bracteolata*, *S. eximia*, *S. lepidota*, *S. parvifolia*, *Vatica* sp. in Malaya. **pumilus**, 2 mm., in *Artocarpus chaplasha*, *A. lakoocha*, *Ficus infectoria*, *Sterculia campanulata*, *S. villosa*, *Terminalia bialata*, *T. manii*. **quadrispinosulus** in *Swietenia macrophylla*.

X. recidens in *Albizzia lebbek*, *Shorea robusta*, *Terminalia bialata*, Bengal to New Guinea. **resecans**, 2·5 mm., in *Dipterocarpus pilosus* and *D. turbinatus*. **riehli** *(Progenius)* in *Afzelia bijuga*, *Excaecaria agallocha*, *Sonneratia apetala* in coastal forests from E. Africa to Celebes. The gallery-system is simply bifurcate or trifurcate in a transverse plane often very crowded at 10 entrance-holes to the square inch (Beeson, 1930, fig. 5). **rodgeri**, 1·7 mm., in the Andamans in *Myristica andamanica*, *Pterospermum acerifolium* and *Terminalia procera*; a variety of the same, **privatus**, also attacks *Anacardium occidentale* and *Terminalia bialata*. The gallery-system is dendritic with long branches undulating towards the centre of the log and sending out secondary branch-galleries and occasional links (Beeson, 1930, fig. 6). **rudis**, 2·8 mm., in *Artocarpus integrifolia* in Ceylon and South India and *Shorea leprosula* in Malaya. **saxeseni**. This Holarctic species occurs in *Fraxinus excelsior hookeri* and *Prunus padus* in the Himalayas; the gallery-system has irregular wide chambers expanded in an axial plane.

X. schlichi, 3·1 mm., in *Bridelia tomentosa*, *Dipterocarpus cornutus*, *Shorea leprosula*, *S. parviflora*, *S. robusta*, Assam to Malaya. **semigranosus**, 2·4 mm., in *Albizzia lebbek*, *A. moluccana*, *A. stipulata*, *Artocarpus chaplasha*, *Cedrela toona*, *Cinnamomum camphora*, *Dalbergia latifolia*, *Dillenia pentagyna*, *Eugenia jambolana*, *Holigarna arnottiana*, *Hopea wightiana*, *Kayea floribunda*, *Lagerstroemia flosreginae*, *Leea sambucina*, *Mangifera indica*, *Quercus serrata*, *Sageraea laurina*, *Shorea robusta*. *Sterculia villosa*, *Styrax benzoin*, *Terminalia tomentosa*, and many other hosts in India to Samoa. The male beetle is figured in fig. 113, No. 4; the larva is described in Gardner, 1934, p. 16, length 3·5 mm. A fairly common species in branchwood and poles making a short curved gallery with minor branches and a part of one gallery enlarged into a communal chamber for larvae, all in a transverse plane. It prefers moist fresh wood and is more abundant in wood in shaded places. The frass is ejected from the entrance-hole in coherent cylinders which may reach a length of 1½ inches before breaking [fig. 113, No. 2]. The life-cycle may be completed in 6 weeks and there may be a sequence of 6 generations a year. (Beeson, 1930, pp. 79–81, fig. 7).

seminitens in *Calophyllum walkeri* in Ceylon. **senchalensis** in *Symplocos theaefolia*. **sexspinosus** *(Eccoptopterus)* from India to Celebes in *Albizzia lebbek, A. odoratissima, Anacardium occidentale, Bassia latifolia, Bridelia retusa, Canarium euphyllum, Diospyros oocarpa, Dipterocarpus turbinatus, Erythrina indica, Myristica andamanica, Pterocarpus dalbergioides, Shorea robusta, Sterculia ornata, S. villosa, Tectona grandis, Terminalia bialata*. **sereinuus** in *Hibiscus macrophyllus, Endospermum malaccense, Sterculia macrophylla, Whitfordiodendron pubescens*. **shoreae** [fig. 113, No. 5] in *Amoora wallichii, Dipterocarpus pilosus, Echinocarpus dasycarpus, Ehretia acuminatus, Lannea grandis, Phoebe lanceolata, Shorea assamica. S. robusta, Terminalia chebula, T. myriocarpa, T. tomentosa, Vatica lanceaefolia*, United Provinces to Burma. The gallery-system consists of a branched mother-gallery in a transverse plane connected with link-galleries on the surface of the sapwood and there are axial subtriangular chambers at various places on the main galleries and on the surface link-galleries. A brood may emerge in 3 months but development ordinarily continues for the whole year so long as the timber remains moist until the main swarming-periods of March–May and October, November. (Beeson, 1930, pp. 82, 83, pl. ii). **sibsagaricus**, 3·5 mm., in *Casearia glomerata, Ehretia acuminata, Sapium eugeniaefolium* in Assam, Bengal. **siclus**, 5·9 mm., in *Dipterocarpus baudii* in Malaya; the gallery-system lies in one horizontal plane, the entrance-tunnel forking at a wide angle, and the branch-galleries forking in a very regular pattern. Up to 8 branches each occupied by a mature female occur in one system. (Browne, 1936, p. 4, fig. 4). **similis**. The beetle, 2·3-2·5 mm., is a polyphagous abundant species in the Indo-Malayan Region. Over 50 food-plants are recorded which include representatives of all the important timber trees and associated species in forests of Ceylon, India, Burma and Malaya. (See Beeson, 1930, p. 84; Browne, 1936, p. 125). Beetles occur throughout the year. The shortest observed period in which a brood may mature and emerge is 3 months from the date of felling of the tree, while the longest period expiring before emergence is 23 months from the date of felling; continuous straggling emergence of what is presumably a series of broods has been recorded for a period of 10 months from the commencement of swarming. When an infestation by *similis* is heavy and pure the emergence-period is short and sharply defined, but when the infestation is light or there is competition with other borers the period of emergence is much prolonged. The gallery-system is of the same type as in *testaceus* (e.g., in fig. 119) which breeds under the same conditions with which *similis* is frequently associated. Beeson, 1930, pp. 84, 85, (as submarginatus Blfd. sensu lato). **sisyrnophorus**, 3·5 mm., in *Dryobalanops aromatica, Xerospermum* sp. in Malaya. **sordicauda** in *Dolichandrone stipulata, Lannea grandis, Macaranga denti-*

culata, *Stereospermum neuranthum*, *Terminalia chebula*, *Xylia dolabriformis* in Burma-Malaya. **sordicaudulus** in *Fagraea gigantea*, *Macaranga denticulata*, in Burma-Malaya. **spatulatus**, 5·4 mm., in *Xanthophyllum* sp. **subgranulatus**, 1·2–1·5 mm., in *Vatica lanceaefolia*. **submarginatus** see **similis**. **subnacrus** in *Shorea curtisii*, *S. platycarpa*. **subnepotulus**, 2 mm., in *Albizzia lebbek*. **subparallelus** in *Artocarpus kunstleri*. **subsimilis** in *Acrocarpus fraxinifolius*, *Cinnamomum obtusifolium*, *Tectona grandis* in Assam-Burma. **sulcatus**, 3 mm., in *Artocarpus lakoocha* in Assam. **suturalis**, 2·3 mm., in *Terminalia myriocarpa*, Assam to Tonkin.

X. tegalensis, 5 mm., in *Cinnamomum obtusifolium*, *Dysoxylum binectariferum*, *Phoebe lanceolata*, *Vatica lanceaefolia*. **terminatus** in *Holigarna arnottiana*, *Lantana aculeata*.

Xyleborus testaceus

Is probably the commonest shothole borer of timbers in the Indo-Malayan region and a dominant species extending far into the adjoining tropics, moreover frequently introduced in exported timber to Australia and Africa. It was previously known under the name *kraatzi* Eichh.

The beetle is 2–2·4 mm., cylindrical, testaceous to reddish-brown, the declivity with a few tubercles. Over 100 food-plants are known for this species in the Oriental Region which include all the important forest trees of India and Burma. A list is given by Beeson, 1930, p. 60. It does not attack living trees in the forest, except those on the point of dying. Whether there is one widely distributed polyphagous species or a group of closely allied specific and subspecific forms is uncertain until bio-morphological studies have been completed. For practical purposes it may be accepted that the *testaceus* form occuring in any district is a widely polyphagous species.

G a l l e r y - s y s t e m : The pattern is on the same type as for *cognatus* [fig. 119] (see also Beeson, 1930, fig. 3). The galleries keep fairly regularly to the horizontal plane of the entrance-tunnel from which branches are sent off right and left; in poles of small dimensions and branchwood these side-branches are short and soon bifurcate towards the central axis; in logs and large timber the side-branches often run for several inches parallel to the circumference before ramifying; extensions made towards the heartwood are often curved or sinuous. No brood-chambers or link-galleries are made on the surface of the sapwood. Linkage within the wood may occur when the infestation is crowded and separate brood-tunnels intersect. The walls of the tunnels are blackened and show up conspicuously in light coloured woods which are thereby spoiled for ornamental purposes [fig. 113, No. 1].

E m e r g e n c e - p e r i o d : Emergence is continuous throughout the year and for 12 months from commencement; well-marked

periods of maximum abundance occur in October and December–February and February–April in north India.

X. tristis in *Vatica lanceaefolia*. **tunggali**, 2·4 mm., in *Canarium* sp., *Dryobalanops aromatica*, *Shorea laevis*, *S. parvifolia*, in Malaya.

X. undulatus in *Shorea robusta* in Bengal. **ursus** in *Swietenia macrophylla* in Malaya.

X. velatus, 2·2 mm., in *Quercus serrata*, *Thunbergia grandiflora*, *Tectona grandis* and *Xylia dolabriformis* in Burma. **versicolor** in *Semecarpus gardneri*. **vicarius**, 2·9–3 mm., in *Pterocarpus dalbergioides*, *Sterculia campanulata*, *Terminalia bialata* in the Andamans. The species extends as far as New Guinea. The gallery-system resembles that of *cognatus* [fig. 119] but is remarkable for the long radial extension of the subsidiary branches which may run inwards for 6 or 7 inches in a moist soft wood of uniform texture as e.g., of *Sterculia campanulata* (Beeson, 1930, fig. 8).

Xyloctonus andamanus in *Dipterocarpus turbinatus*, *Sideroxylon longipetiolatum*. **X. mimusopis** in *Mimusops elengi*, *M. hexandra* in Ceylon. **X. scolytoides**, 2·4 mm., in *Bassia latifolia* and *Dichopsis polyantha* in India. The mother-gallery is monogamous and transverse, grooving the sapwood; the larval galleries are longitudinal and crowded, deeply entrenched in the bark.

SILPHIDAE

This family of Burying Beetles, so familiar in temperate lands, is of less appreciable importance in the Indian Region, where carrion-eating vertebrates are more abundant. SILPHIDAE are more commonly seen in the Himalayas, where they inter corpses in the ground, excavating freely and cutting through subterranean roots to make a grave.

STAPHYLINIDAE

Rove or Rover Beetles or STAPHYLINIDAE are a large family of some 14,000 species of small or very small beetles (a few millimetres long) distinguished by extremely short elytra and large hind wings; a few species reach the exceptional length of one inch. These beetles are the minute insects that fly in the dusk and get into one's eyes as one is driving or motoring. About 2,500 species have been recorded from India, Burma and Ceylon and undoubtedly there are hundreds more to be found.

The habits of the family are most diverse; for the most part their lives are concealed and little is known concerning them. It is generally assumed that many are scavengers but a large degree of entomophagous predatism exists in the family (Baldul). Many are found in dung and carcases, in fungus when fresh and when decomposing; rotting fruit is a great attraction to many; amongst

dead leaves and vegetable debris and under the bark of decaying trees are the habitats of many genera; a few are pollen feeders; many are found in moss on boulders in streams and in their sandy banks; in ground-nests of mammals, in birds' nests, ants' and termites' nests (Cameron). The myrmecophiles and the termitophiles shows some extraordinary vital adaptations and morphological modifications. Many genera are predators of insects, particularly on dipterous and coleopterous borers of fruit, bark, decaying vegetable matter, fungi, dung, etc.; some have developed a specialised mode of life in which some of the larval instars are truly parasitic. The predominant larval type throughout the family is campodeiform, active and predaceous [fig. 121]. Life-histories of Indian species are practically unstudied and their economic importance has not been assessed. Elsewhere the groups predaceous on bark-borers are rated as very useful.

LITERATURE:
Cameron M., 1925, *Catalogue Ind. Ins.*, Part 6—Staphylinidae.
— 1927, *Spol. Zeylan.*, XIV, p. 115, New Staphylinidae from Ceylon.
— 1933, *Rec. Ind. Mus.*, XXXV, iii, pp. 375-377, Description of a new staphylinid beetle from the Punjab.
— 1930, *Fauna Brit. Ind.*, Staphylinidae I, pp. 471, pls. 3, figs. 134.
— 1931, *tit. cit.*, Staphylinidae II, Paederinae, pp. 257, pls. 2, figs.
— 1932, *tit. cit.*, Staphylinidae III, pp. 443, pls. 4, figs,
— 1939, *tit. cit.*, Staphylinidae IV, Part I, pp. 410, figs., Part II, pp. 411-691, pls. 3, figs.

The genus **Aleochara** includes types attacking diptera in fruits, dung, etc.; some species are parasitic in the later larval instars. Species of **Coproporus** live under bark of logs and in rotting wood. **C. minimus** has an emergence-period extending over the 5 colder months. **Cryptobium** and **Rhopalinda** are species associated with termites. **Falagria, Lispinus, Medon** breed under bark of logs. **Oxytelus, Philonthus, Priochirus** occur in decaying plant-refuse and under bark.

Paederus fuscipes. This beetle causes 'spider lick', a form of vesicular dermatitis in man. The complaint is commonest in the hot dry season and is marked by the sudden appearance of a painful red rash on the skin in which one or several vesicles appear and last for a few days. The beetle is about 7–9 mm. long with a blue-black head, orange thorax, greenish-blue elytra and an orange abdomen of which the last 2 segments are bluish-black [fig. 121]. The beetles frequent herbage in moist places, are abundant in rice fields and are attracted to light at night. Eggs are laid in damp soil and hatch in 2 or 3 days. The larva feeds on decaying organic matter and small organisms of wet soil; it has 3 instars and pupates after one week. The pupal period lasts 3 or 4 days.

LITERATURE:
Isaac P. V., 1933, *Agric. Livestock in India*, III, pp. 33-36, pl. ix.
— 1934, *Ind. Journ. Agr. Sci.*, IV, i, pp. 200-202, pl. xiv.

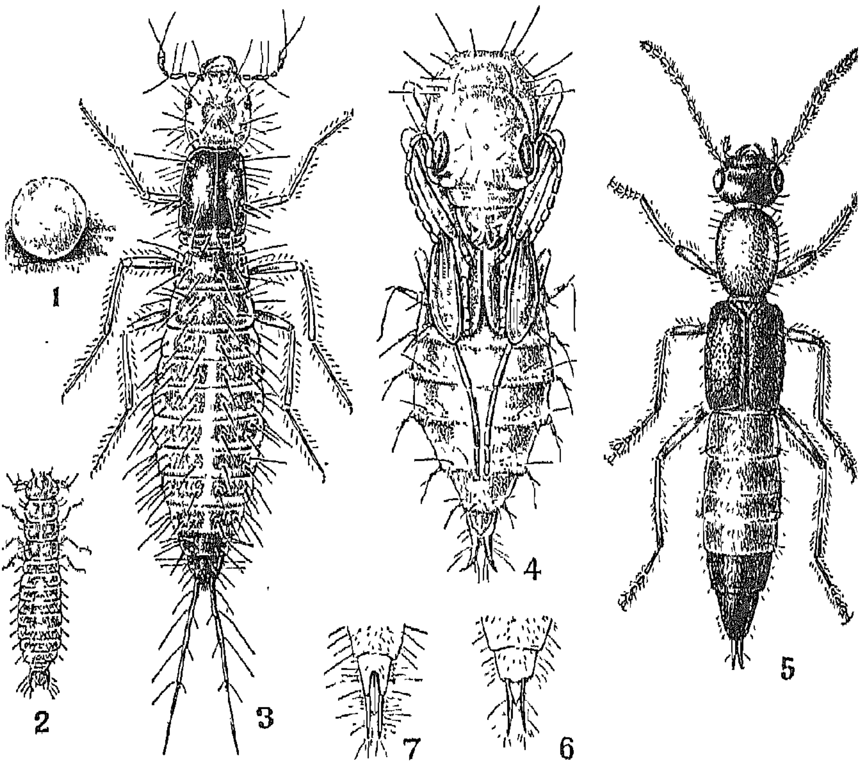

Fig. 121. Paederus fuscipes. Egg, 0.7 mm,, larva, full grown 5 mm., pupa, 4 mm., and beetle, 7 mm. No. 6 is the underside of the end of the abdomen of the female and No. 7 the same of the male.

TENEBRIONIDAE

ONE of the largest families of Coleoptera comprising over 11,000 species, the TENEBRIONIDAE are predominant in the tropics and especially in dry unfertile praiie and deseit iegions, yet by no means uncommon in forests. The beetles aie very vaiiable in form and sculptuie though the colours are generally black or brown; the larvae are fairly uniform in character, some types being known as 'false wirewoims', or 'mealworms'. Oiiginally the food-mateiial of the family seems to have been mouldering and decaying vegetable matter, particularly dry decay, but groups have specialised, on the one hand, in attacking living plant-tissues and, on the other hand, in feeding on animal matter, including excrement. For the purposes of forestiy the Indian geneia of the Tenebrionidae may be assigned to the following groups:

(a) Live under bark or in decaying non-arboreal plants, e.g., *Alphitobius, Catapiestus, Cerypria, Mesomorphus.*

(b) Larvae bore in dead wood, e.g., *Derosphaerus, Encyalesthus, Laena, Setenis, Strongylium, Uloma.*

(c) Larvae and beetles attack living plants, e.g., *Alphitobius, Gonocephalum.*

(d) Predators on wood-borers, e.g., *Corticeus, Lyphia, Palorus.*

The life-cycles of the majority of species living on or in plant-matter are annual; some species, e.g., *Latheticus, Tribolium* living in flour, meal, stored starchy products, etc. have short life-cycles—4 or 5 generations a year.

LITERATURE ON TENEBRIONIDAE:

Blair K. G., 1930, *Ind. For. Rec*, Ent., XIV, v, The Indian species of Palorus and some associated beetles.

Gardner J. C. M., 1929, *Ind. For. Rec.*, Ent., XIV, iv, pp. 121-127, figs. 56-61, Immature stages of Indian Coleoptera (6).

— 1930, *tit. cit.*, XIV, xiii, p. 284, ibid (7).

— 1931, *tit. cit*, XVI, iv, pp. 99-103, figs. 29-45, 53.

Gravely F. H., 1915, *Rec. Ind. Mus.*, XI, pp. 363-365, pl. xxi, figs. 20, 21, The larvae and pupae of some beetles from Cochin, Catapiestus indicus.

Alphitobius laevigatus lives under the bark of logs of many species and in stored seeds, e.g., of *Dipterocarpus, Melanorrhoea,* and *Shorea,* attacked by borers and it is mainly a scavenger. The generation is annual with a prolonged emergence-period (6 months) beetles appearing in all months but in large numbers in the cold season. Other species of *Alphitobius* are injurious to growing crops, e.g., sugarcane.

Ceropria induta is common under bark and in rotten wood, emerging as beetle mainly in March-June.

The genus **Corticeus** contains small beetles that are predaceous on bark beetles (Scolytidae), e.g., **C. beesoni,** 2·2 mm., on *Hylesinus javanus*; **cephalotes,** which has an emergence-period extending over 14 months with greatest abundance in March–June; **flavipennis** on *Cryphalus, Ips, Polygraphus* in the Himalayas; **luteomaculatus** on *Thamnurgides* emerging in March–June; **stebbingi,** 3 mm., on *Polygraphus* and emerging throughout the cold season; **ulomoides,** 4 mm., with an emergence-period of 7 months.

The genus **Derosphaerus** comprises species that bore as larvae in decaying wood. The larva of **D. crenipennis** is described by Gardner, 1929, *Ind. For. Rec.*, XIV, iv, pp. 124, 125, fig. 61.

Encyalesthus exularis breeds in decaying wood of *Dipterocarpus pilosus, Schima wallichii, Shorea assamica, S. robusta.* The larva is a soft-skinned cylindrical borer, 30 mm., and resembles those of *Derosphaerus* and *Setenis*; it is described in 1931, *tit. cit.*, XVI, iv, p. 13, fig. 53.

Gonocephalum depressum. The beetle, 10 mm. long, dull black, usually covered with a crust of sand-particles, often swarms

in large numbers; the larva is cylindrical, shining, yellowish-brown and lives in the soil feeding on the rootlets of weeds and crops, particularly of sugarcane, coffee, tobacco.

Gonocephalum hofmannsegii is injurious to roots of crops. In south India the eggs are laid loose in the soil or in excavations made in the plant attacked and they hatch in 2 or 3 days. The larval life varies considerably with 8 to 16 moults but is confined to the hot weather; the pupal period passed in the soil is short, one week. Normally the generation is annual with beetles emerging after the first heavy rains and remaining inactive till December; sometimes swarming in great numbers in houses.

Coleman L. C. and Kunhikannan K., 1918, *Dept. Agr. Mysore*, Ent. Bull. No. 5, pp. 16, figs. 2, pl. 1, Ground beetles attacking crops in Mysore.

Gonocephalum planatum also lives in the soil feeding on rootlets and decaying vegetation. The beetles sometimes swarm in abundance. They are injurious to sown seeds of *Shorea robusta* and *Xylia dolabriformis* devouring the radicle and other parts of the seed during periods of dry weather after the break of the monsoon.

Hypophloeus see **Corticeus.**

Larvae of **Laena** are borers of decaying wood, e.g., *Abies pindrow*, *Pinus excelsa*, *Quercus dilatata*, *Q. incana*.

Latheticus oryzae, the cosmopolitan flour beetle, is common and persistent in logs with decaying bark and sapwood and in timber attacked by borers; it appears to find suitable nourishment in the debris of wood-borers and continues to occupy such material for 2 or 3 years.

Species of **Lyphia** occur in wood attacked by Bostrychidae; **L, assamensis,** 7 mm., with *Xylothrips religiosa*; **indicola** with *Sinoxylon anale*; **orientalis,** 4 mm., with *Dinoderus bifoveolatus* and *Xylopsocus*; **subopaca,** 5 mm., with *Schistoceros*, *Sinoxylon*, *Xylodectes ornatus*, *Xylothrips flavipes*.

Mesomorphus villiger is recorded as a pest in bungalows on rubber estates in Burma. At certain times of year the beetles are found in large clusters under rotting vegetation or covering large areas of the bark of rubber and other trees in several layers of beetles. At the beginning of the monsoon the beetles invade buildings in millions and congregate in such sheltered dark places as between the ceiling and roof, under wall-mattings, in boxes, inside a piano, etc. They do not appear to feed on any substances except felt, sacking and similar fibrous material, but are a nuisance at night when they become active and crawl and drop everywhere. A correspondent states "... The pest makes life quite unbearable to our womenfolk and gets on their nerves to such an extent that they are unable to stay in the country".

In the spring the beetles begin to leave the shelter of houses and in north India similar mass-swarming takes place in the cold season on trees with the eventual invasion of bungalows by day

and activity after nightfall. The larvae develop in rotting vegetable matter, fermenting hay, rotting jute sacking, etc.

Opatrum see **Gonocephalum**

The genus **Palorus** is composed of small elongate reddish beetles living under bark and preying on Scolytidae. Some species are of wide distribution and occur in association with numerous different species of trees, which indicates considerable adaptability as to prey, e.g., **P. beesoni**, 2·5–3 mm., is associated with Scolytidae of *Boswellia serrata*, *Butea frondosa* and *Ficus* spp.; **cerylonoides**, 3 mm., with *Cryphalus*, *Poecilips*, *Sphaerotrypes* (Scolytidae); **longifoliae** and **shoreae** have food-plants of the same name.

Larvae of **Setenis** are soft-skinned, cylindrical, with 2 posterior spines on the 9th tergite, the anterior legs distinctly larger than the other 2 pairs.

Setenis confusa breeds commonly in dry, rotten sapwood of *Shorea robusta*: the larva reaches a length of over 60 mm. (it is described by Gardner, 1929, *Ind. For. Rec.*, XIV, iv, pp. 21–22); beetles frequent logs from May to September.

Setenis cribrifrons bores in rotting wood of *Alnus nitida*, *Cedrus deodara*, *Pieris ovalifolia*, *Quercus dilatata*, *Q. incana* in the Himalayas. The larva, 40 mm., is described in 1929, *tit. cit.*, pp. 122, 123, figs. 56–60. Beetles emerge in May, June.

Setenis furva bores in *Ficus* spp.; the larva, 40 mm., is described *tit. cit.*, p. 124.

Setenis indosinica another borer of rotting wood; the larva 50 mm., is described in 1930, *tit. cit.*, XIV, xiii, p. 284.

Larvae of **Strongylium** are also borers of dead trees; they are cylindrical, more or less soft-skinned, the caudal segments more strongly sclerotised, the dorsal margin of the 9th tergite dentate and the truncate face below with paired spines.

Strongylium anthracinum in *Cinnamomum cecidodaphne*, emerging in June.

Strongylium beesoni in *Engelhardtia spicata*, *Terminalia myriocarpa*, and **S. clathratum** in *Quercus lanceaefolia*, the beetles emerging in May.

Strongylium interruptum. The rotten-wood-boring larva is described in 1931, *Ind. For. Rec.*, XVI, iv, p. 100, figs. 39–41. **S. parabolicum** likewise in *tit. cit.*, p. 99, figs. 20–33.

Strongylium sobrinum feeds in *Engelhardtia spicata* and *Quercus lanceaefolia*; the larva is described by Gravely, 1916, *Rec. Ind. Mus.*, XII, pl. xx, figs. 7, 8. Beetles emerge in May after an annual life-cycle.

Tribolium castaneum, 5 mm., is a warehouse and grain shop pest, a cosmopolitan flour beetle, but it also occurs throughout India and the East abundantly in timber, manufactured wooden articles, bamboos, seeds, dried fruits, etc. in which the beetles can find shelter and organic debris for food; it is supposed that the

insect is a scavenger rather than a predator in the tunnels of true wood and bark borers.

The genus **Uloma** comprises species that are larval borers of decaying bark and wood.

U. orientalis in *Anthocephalus cadamba*; **polita** in *Shorea robusta* and *Terminalia* spp,

Uloma rubripes in *Phoebe lanceolata*, *Pinus longifolia*, *Quercus incana*; the larva is elongate-cylindrical, a large tergite forming the greater part of the wall of the cylinder, the 9th segment ellipsoidal without spines or processes, and is described in *Ind. For. Rec.*, XVI, iv, p. 12, figs. 43–45. The life-cycle is annual.

U. scita in *Albizzia* sp., *Pinus longifolia*, *Quercus incana*.

TROGOSITIDAE

MEMBERS of this small clavicorn family vary very much in the form of the adult, from elongate and cylindrical to convex and elliptical. Representatives of several genera are entomophagous and typically on bark and wood boring insects. There is no monograph in Indian literature on this group.

Acrops birmanica is predaceous on some of the bark-boring fauna of *Shorea robusta*; its life-cycle is annual, beetles emerging in April–June.

Alindria orientalis, a black, rather flattened beetle, 13–15 mm., is predaceous on bark and sapwood boring larvae including *Chrysobothris andamana* and *C. beesoni* (Buprestidae), *Oleneccamptus curvipes* (Cerambycidae) and *Sinoxylon* and *Schistoceros* (Bostrychidae).

Melambia cardoni, black, flattened, 14–16 mm., is predaceous on Bostrychidae and sapwood-boring Cerambycidae in logs of numerous species of trees. The larva, 25 mm., has nearly cylindrical body-segments but is depressed anteriorly and has a pair of hooked processes on the 9th tergite; see 1931, *Ind. For. Rec.*, XVI, iv, pp. 95, 96, figs. 46–52. The life-cycle is annual with beetles emerging in June, July.

Melambia memnonia, 14 mm., **M. pumila,** 10 mm., and **M. tokkensis** are also predators of Bostrychidae and small Cerambycidae and possibly Buprestidae. Emergence occurs in June, July.

Temnochila coerulea is predaceous on the bark-borers of Himalayan conifers, viz., *Ips* and *Polygraphus* (Scolytidae). The larva is elongate and parallel, the segments furnished with corneous dorsal plates, the sides with scanty bristles and the posterior extremity with a pair of stout hook-like cerci.

Tenebroides mauritanicus is a cosmopolitan pest of cereals and grain-products (flour, bread, etc.) and is known as the 'Cadelle'.

The beetle is flattened, about 1/3rd of an inch long, brown to black in colour. The full grown larva which resembles that of

melambia is about 3/4 of an inch long, white, moderately hairy with distinctly cylindrical abdominal segments, the ninth with a dorsal plate bearing two heavily sclerotised cerci. The females are long-lived and may lay more than a thousand eggs in small clusters which hatch in a few days to two weeks. The larval period may be completed in 4 weeks or it may live over one year if starved. The pupal period lasts one to three weeks. In warm climates there are 3 or 4 generations in a year; in colder climates the winter is passed as a hibernating larva or beetle. The food of the larva consists of grains, flour, dried seeds and fruits; it is not predaceous. For pupation the larva bores into soft wood or other suitable substances and thus may damage the woodwork of granaries, bins, and boxes used for storing food-stuffs, dunnage in the holds of grain-ships, etc.

COLLEMBOLA

THE ORDER COLLEMBOLA

THIS order of primitively wingless insects without metamorphosis has not been studied much in India after the early work of Imms. Less than one hundred species have been identified in the whole Order. They are much less abundant in the plains and tropical forests than in the cooler temperate forests of the Himalayas, and some species are found above snow-level. The most interesting morphological features of the Collembola or Spring-tails are on the six-segmented abdomen of which the appendages of the first segment are united to form a median ventral tube which is adhesive at the tip. Many are active jumpers, and most possess an apparatus for this purpose. The appendages of the 3rd segment are minute, forming a catch, or stud, which holds a forked process, hinged by a broad base to the 4th segment. Normally this process, the spring, is folded against the under surface of the abdomen and kept in place by the stud on the 3rd segment. When released from the stud the pressure of strong muscles forces the fork down, so that it strikes against the ground, throwing the insect into the air.

Ecology: The spring-tails are minute soil insects feeding on decaying organic debris in humus or on the moulds and minute algae growing in such places and also on the skin of rootlets, stems, bulbs and fallen fruits and seeds. The injury to plants consists in scraping away the epidermis and then the softer tissue until a depression or hole is formed. Decomposition of the plant-tissues accompanied by fungus-attack may follow.

The oldest known fossil insect, *Rhyniella praecursor*, is a species of Collembola described by Hirst and Maulik in 1926 from the Middle Devonian; it lived three hundred million years ago.

"Researches by forest entomologists have shown that the preparation of the primeval forest floor out of the bare original elements of disintegrated rock and unconverted plant humus has been through countless ages, the task designed by Nature for these tiny insects and another important soil group, the mites. Some thousands of species are now known, of which the great majority are ceaselessly engaged upon the work of preparing minute particles of humus and incorporating them in the soil.

Injurious groups: But, as in almost all cases of insect groups, there are specialized forms which have broken away from the original role and have taken on a new line of evolution. Among these are the Globular Springtails, or family Sminthuridae. . .These insects have departed from the original habit of feeding on rotting or decayed vegetable material, and have adopted instead the habit of attacking the delicate tissue of living plants. In their natural surroundings owing to their small size and to the delicacy of their mouth-parts, the damage which they do is generally (though not by any means always) too slight to be considered an economic loss" (Tillyard).

"The greatest damage by springtails is done to young, tender plants, especially to seedlings. Some species prefer the upper or the lower surface of a leaf to work on whereas other species work on either surface. The springtails make irregular holes in leaves, gradually piercing the leaf completely, or characteristically leaving the epidermis at the end of the puncture intact. They feed also at wounds made by flea beetles, potato beetles, and other insects. Sometimes they completely destroy cotyledons and other leaves. In many instances springtails feed collectively, several or many individuals cooperating to enlarge the same opening. . .

Many species injure the stems of plants just below the surface of the ground and often cut through them. On roots springtails cause injury by gnawing pits and by destroying roothairs and small rootlets. As a result the growth of the plant may be stunted. On seeds these insects do more or less damage by eating out pits. On bulbs they not only make pits but also excavate the interior, sometimes completely" (Folsom).

In soil which has been partially sterilised by exposure to direct solar heat or ground-fire, and thereafter cooled and moistened by monsoon rains, the Collembola may increase very greatly. It is quite possible that root-rot in tropical countries originates from the direct damage caused to tender roots by the vast numbers of these small insects during the favourable conditions for multiplication—conditions which are abnormal though temporary (Baweja, 1939).

Species of **Achorutes** and **Isotomurus** swarm in great numbers on the surface of still water. **Entomobrya** and **Sinella** occur in

ants' nests, **Pseudocyphoderus** in termites' nests.

LITERATURE ON COLLEMBOLA:

Carpenter G. H., 1917, *Rec Ind. Mus.*, VIII, pp. 561-568, Zoological results of the Arbor expedition.

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Mukerji D., 1932, *tit. cit.*, XXXIV, pp. 47-79, figs. pl., Description of a new species of Collembola and its anatomy (Literature).

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DERMAPTERA

THE ORDER DERMAPTERA

EARWIGS of the world do not total much more than 900 species (of which perhaps 150 species occur in the Indian region), but they are considered to form a distinct Order, rather than a section of the Orthoptera, and are monographed in the *Fauna of British India* by Burr. Their most characteristic features are the small rectangular, veinless, stiffened flaps forming the elytra and rarely covering more than the basal segments of the abdomen; the ample membraneous hindwings which are folded by methods probably more complex than those employed by any other group of insects; the paired forceps attached to the last abdominal segment which has the muscle development needed to work them. These characters are not uniformly present; in some species the elytra and hindwings are totally absent or rudimentary; the forceps have a great diversity of form but are almost invariably simpler in the female than in the male.

Ecology: Although earwigs are commonly encountered in vegetation, in various living and more or less decayed parts of herbs and trees, very little is known of their life-histories. The adults are largely carnivorous and probably omnivorous feeding on small soft-bodied insects and spiders; it is not proved that they damage living tissues of plants. Some species are predators in so far as they lie in wait to catch their prey **(Elaunon, Labidura).**

The forceps are used in seizing and carrying prey and as weapons of defence; they are occasionally used to unfold and fold the hindwings and lift up the elytra; they are not used to facilitate pairing. The female of some species **(Diplatys, Acrania)** has well-developed maternal or social instincts, brooding over her clutch of eggs until they hatch and protecting the nymphs until they become independent. As a home for the eggs and brood of nymphs some females select tunnels of wood-borers, e.g., of large Bostrychidae, or the beeholes of *Xyleutes ceramica* (Cossidae), or the tunnels of bark-boring Curculionidae. Earwigs are frequently found in association with damage to trees and are liable to be wrongly incriminated by an uninformed observer.

LITERATURE ON DERMAPTERA:

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earwig, Labidura lividipes.
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Chopard L. and Chatterjee N. C., 1937, *Ind. For. Rec.*, Ent., III, No. 1, pp. 3-5, (Dermaptera of sandal, 31).
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DIPTERA

THE ORDER DIPTERA

RECENT estimates put the number of named species of two-winged flies of the world at 75,000, making the Order DIPTERA the fourth largest order with 12 percent of the total insect fauna. A relatively small number of families and species of flies are known to be important to forestry, more for want of investigation than because Diptera are intrinsically neutral. Many groups are as important and injurious to the forest officer as to the forest owing to the numerous kinds of flies that bite, or suck blood, or transmit the diseases of human beings.

The various larval and adult modes of life may be grouped thus:—

Larva mines or destroys bud or fruit, e.g., Agromyzidae, Itonididae, Trypetidae
— **forms a gall**, e.g., Itonididae
— **mines leaf**, i.e. many acalyptrate families
— **lives in soil**, e.g., Asilidae, Tipulidae
— **lives in water**, e.g., Culicidae, some Syrphidae, Tabanidae
— **feeds on decaying vegetable matter**, e.g., Muscidae, Mycetophilidae
— **feeds on decaying animal matter**, e.g., Calliphoridae, Muscidae, Phoridae
— **is predaceous**, e.g., some Culicidae, Syrphidae
— **is parasitic**, e.g., Bombyliidae, Oestridae, Tachinidae

Adult is predaceous, e.g., Asilidae
— **sucks blood**, e.g., Culicidae, Psychodidae, Simuliidae, Tabanidae
— **feeds by sponging up liquids or soluble substances**, i.e., many families.

Classification: An excellent introduction to the order is given by Brunetti in the *Fauna of British India*, 1912, which should be consulted for external anatomy, synoptic keys, etc. A key to families is provided by Fletcher, 1926. For the classification of the Diptera on lines of phyletic development this book adopts the conspectus of Brues and Melander, 1932, as set forth in the following series:

Synopsis of the families of the Order DIPTERA

Suborder **NEMATOCERA**	
TIPULOIDEA	**Tipulidae**
PSYCHODOIDEA	**Psychodidae**
CHIRONOMOIDEA	**Chironomidae**
	Ceratopogonidae
	Simuliidae
CULICOIDEA	**Culicidae**
MYCETOPHILOIDEA	**Mycetophilidae**
	Sciaridae
	Itonididae
Suborder **BRACHYCERA**	
Division **ORTHORRHAPHA**	
STRATIOMYIOIDEA	**Stratiomyiidae**
TABANOIDEA	**Tabanidae**
ASILOIDEA	**Bombyliidae**
	Asilidae
Division **CYCLORRHAPHA**	
Series ASCHIZA	
PHOROIDEA	**Phoridae**
SYRPHOIDEA	**Syrphidae**
Series SCHIZOPHORA	
MUSCOIDEA CALYPTRATA	**Tachinidae**
	Calliphoridae
	Muscidae
	Oestridae
MUSCOIDEA ACALYPTRATA	**Trypetidae**
	Sapromyzidae
	Agromyzidae
	Chloropidae
Section PUPIPARA	
HIPPOBOSCOIDEA	**Hippoboscidae**

The above synopsis omits the names of numerous families and some of the family series used by Brues and Melander; it includes all the family names discussed in this book and places them in the serial order adopted by Brues and Melander. The spelling and synonomy of some of the family names differ for various reasons from those forms used by Brues and Melander.

LITERATURE ON DIPTERA:

Barrand P. J., 1934, *Fauna Brit. Ind.*, Diptera, Culicidae, Megarhini, Culicini, 463 pp., 8 pls.

Brunetti E., 1912, *Fauna Brit. Ind.*, Diptera, Nematocera, 581 pp., 12 pls.

— 1920, *tit. cit.*, Diptera, Brachycera, 401 pp., 4 pls.

— 1923, *tit. cit.*, Diptera, III, Pipunculidae, Syrphidae, Conopidae, Oestridae. 424 pp., 85 figs., 6 pls.

Christophers S. R., 1933, *tit. cit.*, Diptera, Culicidae, Anophelini, 371 pp., 3 pls., figs.

Fletcher T. B., 1926, *Agr. Res. Ins.. Pusa,* Bull. No. 162, Tentative Keys to the orders and families of Indian insects, pp. 86-100.

Russell, H., 1922, *Journ. Bomb. Nat. His. Soc.*, XXVIII, pp. 370-380, 704-718, 957-969, pls. V, On Indian parasitic flies.

Senior White R., 1923-28, *Catalogue of Indian Insects*, Part 2, Culicidae; Part 3, Bombyliidae; Part 4, Trypetidae; Part 12, Tabanidae; Part 15, Cecidomyidae.

Senior White R., Aubertin D. and Smart J., 1940, *Fauna Brit. Ind.*, Diptera, VI, Calliphoridae, 288 pp., 152 figs.

AGROMYZIDAE

SMALL acalyptrate muscoid flies which are usually leaf-miners, cambium-miners or seed-borers in the larval stage. Only one forest species has been studied.

Ophiomyia lantanae, The Lantana Seedfly.

A small black fly, with a wing-span of 6 mm., (something like an eye-fly) which oviposits in the green, brown and black fruits of *Lantana aculeata* in which the kernel has hardened, laying usually only one egg per fruit. The egg, about 1 mm. long, hatches in 1 or 2 days during the hot weather and monsoon season and in 3–4 days in the cold season. The yellowish larva feeds within the outer pulp of the fruit and sometimes enters the seed and destroys the embryo also; when fullgrown it is about 2·5 mm. long. The puparium is dirty whitish, about 2 mm. long. and is formed inside the skin or between the pericarp and kernel of the mature fruit. A lantana berry in the early stages of attack shows whitish or lighter coloured patches of skin; later the remains of the fruit dry up and it falls off.

The life-cycle from oviposition to emergence is 9 days in April, 9–10 in May, 10–11 in June, 12 in July, 12-13 in August, 13-14 in September, 15 in October, 23–42 during the period late October–December. In the colder months, November-March, the pupal period lengthens from 18–31 days and becomes a resting stage. Fruits attacked in January produce flies in April.

A sequence of 21 generations a year is possible in north India and still more in south India provided lantana fruits are available. But if fruits are absent it can oviposit in the flower-head or peduncle and develop successfully in a flower-head. The life of the fly in the warm weather is only a few days.

Economic importance: *Ophiomyia lantanae* was introduced from Mexico to Hawaii in 1902 (see history of the control of lantana by introduced insects, Part Two). From Hawaii it

was introduced to New Caledonia about 1908 and to Fiji in 1911 and to Queensland in 1917 and to Hongkong in 1933. Attempts were made to introduce it to India by the Department of Agriculture, Mysore, first in 1913 and later successfully in 1921. In that year 273 flies were released in Bangalore. No trace of attack on lantana berries in that neighbourhood was found in the next and subsequent years and it was concluded that the introduction had failed. Further attempts were made by the Government Entomologist, Mysore, in 1927 and 1932 which also were recorded as unsuccessful. But in between 1932 and 1934 evidence was unexpectedly obtained of its occurrence in Cochin, Travancore, Madras, Mysore, Coorg, Bombay, United Provinces, Punjab and Burma. Subramaniam was reluctant to deduce from this evidence that the Bangalore liberations of 1921 had survived or that dispersal on so extensive a scale was possible in 12 years from a small initial colony and concluded that the fly had been present in India perhaps ever since the introduction of lantana. (Subramaniam, 1934). But Rao's surveys of the lantana fauna had definitely shown it was absent from India in 1919 (Rao, 1920); the high biotic potential of the fly and the influence of upper air currents are sufficient to account for its rapid dispersal (Beeson, 1940).

When first released in Hawaii it increased very rapidly and affected a high percentage of berries. In Queensland and New South Wales it spread rapidly and crossed natural barriers and considerable distances in which lantana was absent.

The reputation gained by the fly arises from its alleged ability to destroy the power of germination of the seed and thereby check the dissemination and regrowth of lantana. Tests carried out in India show that the germination capacity of lantana seed varies considerably with the soil on which it lies and is on the average very low, less than 15 percent; the removal or decay of the pulp of the fruit increases the germination capacity. Fruits attacked by the fly definitely germinate and the germination percentage is of about the same order as in unattacked fruits. The fly cannot therefore be regarded as a factor of importance in preventing the germination of fallen lantana berries; it may have a small economic value in preventing dispersal of seeds by birds and other vertebrates by rendering the berries unattractive to them.

O. lantanae in India is now subject to parasitism by at least 8 species and in spite of its short life-cycle it is not abundant. It is not a species worth propagating artificially for the biological control of lantana.

LITERATURE:

Ramachandra Rao, Y, 1920, *Mem. Dept. Agr.*, V, 6, pp. 240, 241, 279, Lantana insects in India.

Beeson, 1920, *Ind. For.*, XLVI, pp. 535-537, The insect pests of lantana.

Kunhikannan, K., 1924, *Agr. Journ. Ind.*, XIX, pp. 504-508, Lantana flies in Hawaii.

Subramaniam T. V., 1934, *Ind. Journ. Agr. Sci.*, IV, pp. 468, 470, pl. XXXI, The lantana seed fly in India.
Administration Reports, Dept. Agr., Mysore, 1929-1934.
1938, *Ind. For.*, LXIV, p. 434, Lantana seedfly.
Beeson and Chatterjee N. C., 1940, *Ind. For. Rec.*, Ent., VI, No. 3, pp. 45, 51, Possibilities of control of lantana by indigenous pests.

ASILIDAE

MODERATE to large sized bristly flies with an elongate thorax and abdomen and long powerful legs; the eyes large and protuberant, the proboscis a stout and horny beak directed downwards, formed of the labium closed above by the labrum-epipharynx and enclosing a hollow needle-like piercing organ (hypopharynx) and two long narrow maxillae. The ASILIDAE, or Robber Flies, are entirely predaceous and will attack insects much larger and more powerful than themselves, such as formidable Hymenoptera and Coleoptera, as well as the softest and weakest Diptera and Rhynchota. Some hawk on the wing but most lie in wait on a leaf or stone. The prey is surprised by the quick flight of the robber fly, which strikes rapidly with its proboscis, usually at the back of the head of its prey, injecting a virulent poison that is secreted in the salivary glands in the thorax, and killing the prey instantaneously. The blood and body-fluids are sucked out, a meal which may take a minute or an hour according to the size of the victim. Asilids hunt without cessation; as soon as one insect is devoured another is captured.

The larva is elongate cylindrical having a small dark head and 12 body-segments with a hard granular skin. It lives in sand, earth rich in humus, decaying wood, or in the tunnels of wood-borers and carpenter bees; some species are predaceous, others scavengers. The pupa has a horny pupal skin with girdles of spines or bristles on the abdomen and spinous projections on the head by means of which it crawls out of the larval environment to release the fly in the open air. The genera *Hyperechia*, *Maira* and *Pogonosoma* have wood-boring predaceous larvae. Flies of the genus *Promachus* prey on honey-bees, and other Hymenoptera and Diptera. The larval life is spent in the soil where the larva attacks and feeds on cockchafer grubs.

LITERATURE ON ASILIDAE:
Bromley S. W., 1935, *Rec. Ind. Mus.*, XXXVII, pp. 217-230, New Asilidae from India.
— 1938, *Ind. Journ. Agric. Sci.*, VIII, pp. 863-868, New Asilidae from India, ii.

Hyperechia xylocopiformis, like other species of *Hyperechia*, is a large hairy fly resembling a carpenter-bee, *Xylocopa tenuiscapa* (Apidae) on which it is predaceous. The *Hyperechia* larva attacks the *Xylocopa* larva in the cell of the latter in the wood and sucks it completely dry in the course of a few days; it then bores out of the cell into the wood alongside and pupates at the

end of a tunnel. The pupal skin is stoutly constructed and provided with frontal processes and flanges on the abdomen by means of which the pupa bores its way out to the surface of the wood to allow the fly to escape.

Laxenecera flavibarbis preys on the little bee, *Apis florea*.

Philodecus femoralis. The larva is predaceous on grubs of *Alissonotum impressicolle* (Scarabaeidae).

Pogonosoma cedrusa bores in the larval stage in the wood of *Cedrus deodara* and is presumably predaceous on the siricid or cerambycid borers in the timber; flies emerge in May, June.

Promachus apivorus preys on the large black bee, *Apis dorsata*.

Promachus beesoni is predaceous in the larval stage on the grubs of cockchafers which it finds in the soil. The pupa is provided with processes and flanges by means of which it bores its way up to the surface of the ground to allow the fly to emerge. The fly like most species of the genus is probably predaceous on honey-bees.

CALLIPHORIDAE

FLIES grouped together in the calyptrate family CALLIPHORIDAE include with the Chrysomyiinae and Rhiniinae the genera that some authors class in the Muscidae or consider to form a distinct family, the Sarcophagidae. All the flies of this group of about 220 species are saprophytic in their early stages though the larvae of some species are blood-eaters and produce myiasis and others are truly parasitic; some are oviparous, others larviparous. *Lucilia* includes bluebottle and greenbottle flies. *Chrysomyia* is the genus with the most diverse habits ranging from myiasis and the carriage of cholera to predaceous and scavenging habits. *Termitolaemus* preys on termites and *Bengalia* is a robber of ants and termites, the proboscis being specially adapted to seize the pupae or prey from marching columns of ants. The Sarcophaginae are uniformly coloured grey flies with a longitudinally black striped thorax and marbled abdomen, hairy (but not bristly as are Tachinidae). The females are larviparous, laying 40 to 80 larvae which feed in decaying animal and vegetable matter, but some are true parasites on Orthoptera, lepidopterous larvae, adult Coleoptera, scorpions, earth-worms and snails.

Although many of the Calliphoridae might be described as common every day flies it is remarkable that very little is known of their life-history and the periodicity of life-cycle. The ecological information is pre eminently medical.

LITERATURE ON CALLIPHORIDAE:

Patton W. S. and Cragg F. W., 1913, *A textbook of Medical Entomology*, p. 324.

Patton W. S. and Evans A. M., 1929, *Insects, ticks, mites and venomous animals*, Part I—Medical.

Patton W. S., 1917, *Rec. Ind. Mus.*, XII, pp. 185-262, Indian flies of the subfamily Rhiniinae.

Patton W. S., 1920, *Ind. Journ. Med. Res.*, p. 17, pls., Notes on Indian Calliphorinae.
— 1922, *tit. cit.*, IX, pp. 548-574, Some notes on Indian Calliphorinae, Part ii, Lucilia argyricephala Macq. (serenissima Fabr.) The common Indian bazaar greenbottle whose larvae occasionally cause cutaneous myiasis in animals and Lucilia craggi sp. nov. one of the common blowflies of Indian hill stations.
— *1922, tit. cit., pp. 635-653, ibid, Part VI, How to recognise the Indian* myiasis-producing flies and their larvae together with some notes on how to breed them and study their habits.
— 1922, *tit. cit.*, pp. 654-682, ibid, Part VII, Additional cases of myiasis caused by the larvae of Chrysomyia bezziana Vill. together with some notes on other Diptera which cause myiasis in man and animals.
Senior White R., Aubertin D. and Smart J., 1940, *Fauna Brit. Ind.*, Diptera, VI, Calliphoridae, pp. 288, figs. 152.
— Catalogue of Ind. Ins. (in preparation).
Senior White R., 1924, *Rec. Ind. Mus.*, XXVI, pp. 193-283, pls. viii-xix, A revision of the subfamily Sarcophaginae in the Oriental Region.
— 1925, *tit. cit.*, XXVII, pp. 81-96, A revision of the subfamily Rhiniinae in the Oriental Region.
— 1926, *tit. cit.*, XXVIII, pp. 127-140, A revision of the subfamily Calliphorinae in the Oriental Region.
— 1923, *Spol. Zeylan.*, XII, pp. 294-314, pls. i-xi, The Muscidae Testaceae of the Oriental Region.
— 1925, *tit. cit.*, XIII, pp., 209-212, New Ceylon Diptera IV.
— 1927, *tit. cit.*, XIV, pp. 77-84, Notes on Oriental species of the genus Sarcophaga.
— 1923, *Mem. Dept. Agr. Pusa.*, Ent., VIII, No. 4, Notes on Indian Muscidae (1) Calliphorinae testaceae, (2) Rhiniinae.

Bengalia spp. The flies of this genus pounce upon ants on the march carrying larvae and pupae, or on foraging termites; the prey is then torn and sucked by means of the strong raptorial proboscis.

Booponus indicus, a compactly built fly, 5-6 mm. long, is a parasite of the Indian elephant. The larvae bore in the subcutaneous tissue and their presence causes the formation of "warbles" or suppurating swellings on the skin of the body including the head and ears. These abcesses may occur in very large numbers and so close together that the skin appears as if honeycombed after the larvae have bored out in order to pupate; the puparial period is about 10 days.

Calliphora erythrocephala, a palaearctic species of blowfly or bluebottle fly occuring in northern India. The female lays 400 to 600 small eggs on decaying organic matter.

Chrysomyia bezziana is a specifically human myiasis-producing fly. Its larvae occur in evil-looking and foul-smelling ulcers and wounds in the skin and flesh of various parts of the body.

Chrysomyia pinguis, 9 mm.; the larvae feed in decomposing carcases of birds and small mammals.

Chrysomyia rufifacies, 10-12 mm., a common widespread species. The first stage larva feeds in dead flesh and the later larval stages (which have spiny fleshy processes all over the body) are predaceous on the larvae of other necrophagous flies in the same carcase. In Australia it is a pest of sheep, causing myiasis.

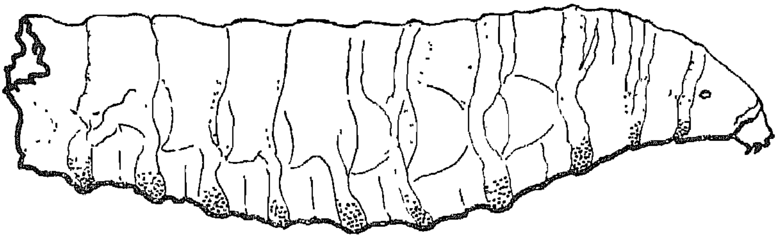

Fig. 122. Larva of Sarcophaga, natural size 15 mm.

Lucilia cuprina is the common bazaar meat and sweet visiting species in India—the socalled "blue bottle fly". In Australia it is a bad pest of sheep, blowing the wool. (see Patton, 1922, as argyricephala).

Lucilia illustris, a palaearctic species occuring in the Himalayas but rare; it breeds in carrion and excrement. (This species is generally referred to as *L. caesar*).

Lucilia papuensis is one of the commonest Indian "green bottles" with similar habits to those of European species of *Calliphora*.

Sarcophaga dux, 7–12 mm., almost cosmopolitan, breeds in a great variety of substances, decaying vegetable matter, dead insects and small animals; it is also recorded as parasitic on locusts and as causing human and bovine tissue myiasis. The female fly attacking a grasshopper strikes at it while it is flying and clings on, causing both insects to drop to the ground together. A larva is deposited beneath the hind wing whence it crawls to the metathorax and bores into the soft cuticle at the base of the wing or between the abdominal segments. Feeding inside the body of the host lasts for 10–30 days and then the larva escapes and pupates in the soil.

Sarcophaga knabi, 6–12 mm., is the common breeder in human excrement in the Orient.

Sarcophaga fuscicauda breeds in dead insects and flesh, in decaying coconut leaves, and it is also parasitic on a lumbricid worm and causes human myiasis. It also attacks living beetles of *Oryctes rhinoceros* (Scarabaeidae) and *Rhynchophorus ferrugineus* (Curculionidae) and the larvae feed internally within the beetle which shows little signs of being parasitised; but it dies in the course of a few days. The larva emerge and pupate in the ground and the fly appears after about a week.

Sarcophaga orientaloides, 7–15 mm., occurs throughout the Indian region, breeding in dead insect larvae, grasshoppers and snails, in human excrement and in flesh.

Termitolaemus marshalli, a small light brown fly with darker markings is predaceous on termite workers.

CECIDOMYIDAE see ITONIDIDAE

CERATOPOGONIDAE and CHIRONOMIDAE

THESE families include Gnats and Midges, flies which by their general appearance and habits are often mistaken for mosquitoes, but by their short probosces and lack of scales on the wing are distinguishable from the Culicidae. The chironomids are not biting flies and are entirely inoffensive. The ceratopogonids are biting blood-sucking midges, and cause annoyance out of all proportion to their minute size, 3 mm. and less.

CHLOROPIDAE

A SMALL acalyptrate muscoid family of which one species is familiar.

Siphunculina funicola is the Eye-fly, a shining black fly, 1·5 mm. long, found throughout the Indian region and throughout the year except from November–February; it is most abundant during the hot season in short breaks after the onset of the monsoon. It is attracted to blood, serum, perspiration and lachrymal secretion and hence is particularly noticed from its habit of persistently trying to settle on one's eyes. It also swarms in clusters on pieces of hanging thread, string, cloth, etc., where it is readily destroyed. The eggs are laid in cracks in cowdung cakes and hatch in 2 or 3 days; the larva feeds actively in the moist dung but becomes torpid if the material dries up. After a week of normal development it leaves the moist region and pupates in a dry place; the pupal period lasts a week. The total life-cycle lasts 16–20 days. Much circumstantial evidence incriminates the eye-fly as a disease-carrier of eye-complaints, sore eyes, conjunctivitis.

Ayyar T. V. R., 1919, *Agr. Res. Inst. Pusa.*, Bull. 89, pp. 35-40, The life-history and habits of the eye-fly.

CULICIDAE

MOSQUITOES, because of their aggressiveness, are perhaps better known to the forest officer than are any other forest insects. The family CULICIDAE, because of its disease-carrying species, is perhaps more fully investigated than is any other family of insects in India. The numerous investigators have been predominantly medical men. The literature of the subject is enormous and only samples of it are listed on page 426.

Classification: The family is classified in 3 subfamilies, **Chaoborinae** (or Corethrinae), **Culicinae** and **Dixinae**; the subfamily Culicinae contains all the true mosquitoes; the 16 members of the other 2 subfamilies are not blood-suckers. The Culicinae contains about 300 species divided into 3 tribes **Megarhini** (6), **Culicini** (251), and **Anophelini** (43) species in India s.l.

The true mosquitoes are distinguished from all other Diptera by (*a*) a characteristic venation of the wing [fig. 123, No. 1], (*b*)

a long proboscis projecting in front of the head [do.], (*c*) Scales (as distinct from hairs) on the wing veins [do., Nos. 6, 7] and (*d*) A fringe of scales along the posterior margin of the wing.

The taxonomy of the larvae of Culicidae has been thoroughly studied and well illustrated descriptions and synoptic keys have been published (see literature).

Life-history: The familiar story of the metamorphosis of the mosquito may be restated briefly :—

The eggs of mosquitoes are deposited on or very near the surface of water singly or in compact masses (egg-rafts) and float on its surface; the number laid by one female varies from about 50 to 400 according to species [fig. 124, Nos. 35-37, 41, 42]. The aquatic larva has a well-developed head, an enlarged thorax and nine abdominal segments. The food of most species consists of minute particles of animal and vegetable matter in the water which are taken into the mouth in a current of water propelled by the movement of a pair of dense tufts of long hair at either side of the head. Some species are carnivorous chiefly on other culicid larvae. Air is breathed through gills at the apex of the last abdominal segment and through spiracles on the dorsal surface of the 8th segment or in some forms (Culicini) at the top of a respiratory siphon on the same segment. When at rest a larva of the Culicini brings the apex of the siphon in contact with the surface-film of water and hangs head downwards [fig. 124, No. 38]; in the Anophelini the larva floats horizontally [fig. 124, No. 43].

The pupa has a comma-shaped globular body and swims actively and breathes by means of a pair of air-tubes on the thorax [fig. 124, Nos. 39, 44]. The life-cycle varies from 2 to 3 weeks.

The female mosquito [fig. 123, No. 1] is distinguishable from the male by setose antennae with comparatively short and inconspicuous hairs; the male has plumose antennae with long dense hairs. Both sexes of many species feed on plant-juices; mosquitoes occur in great abundance in some localities that are practically destitute of terrestrial mammals and their chance of a meal of blood is slight. In any species only the female 'bites' and sucks blood; the irritation of the mosquito bite is due to the injection of the salivary glands secretion or diverticular contents,—a modern view is that the oesophageal reservoirs contain carbon dioxide and a commensal fungus, and by the contraction of the reservoirs the gas and the fungus are forced into the puncture to produce a swelling. A relatively small number of species inject disease organisms into human beings, perhaps not more than 10 species in India.

Culicini: The Culicini include the majority of species of Indian mosquitoes. Some 251 species are monographed in the *Fauna of British India*, by Barraud, 1934. They have been collected at

altitudes of 14,000 feet or more in Kashmir, and 3,760 feet below ground-level (903 feet below sea-level) in the Kolar Gold Mines in south India.

The Culicini, in contradistinction to the Anophelini, contain no species carrying malaria, but they are associated with other diseases. *Aedes aegypti* and *A. albopictus* are known to be carriers of dengue in other parts of the world, and, although very little work has been done on the transmission of dengue in India, it is probable that these two very common species transmit the disease in this country. *Culex fatigans*, one of the commonest domestic mosquitoes in most parts of the country, appears to be the chief carrier of filariasis, together with other likely species as *Mansonia longipalpis*, *Aedes aegypti*, *A. scutellaris* and *Culex vishnui*. Yellow fever has not yet occurred in India, but the Indian race of *Aedes aegypti* (page 428) is capable of transmitting this fever.

Anophelini: The tribe is composed of one genus, *Anopheles*, a general account of which is given on page 429. *Anopheles* mosquitoes can be distinguished from other mosquitoes by *(a)* wing usually spotted with light and dark scaly areas, *(b)* palps about as long as the proboscis, those of the male thickened and clubbed at the ends [fig. 123], *(c)* abdomen either with or without scales but not completely covered with flat appressed scales [fig. 123, compare Nos. 2 and 3], and *(d)* proboscis and body practically in a straight line with one another and at an angle with the surface on which the insect is resting [fig. 124, compare Nos. 40 and 45].

Anopheles larvae are distinguishable by *(a)* absence of a supporting tube (siphon) to the spiracular apparatus, *(b)* their horizontal attitude when at rest or moving at the surface of water and *(c)* the body makes contact with the surface film by means of abdominal float-hairs [fig. 124, Nos. 43, 44].

The group is monographed in the *Fauna of British India* by Christophers, 1933.

M a l a r i a : The disease is caused by 3 species of protozoal blood-parasites; *Plasmodium vivax* is the parasite of benign

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Fig. 123. Characteristics of an anopheline mosquito.

[Nos. 2 and 9 are of a culicine mosquito].

No. 1—*Anopheles*, female mosquito.

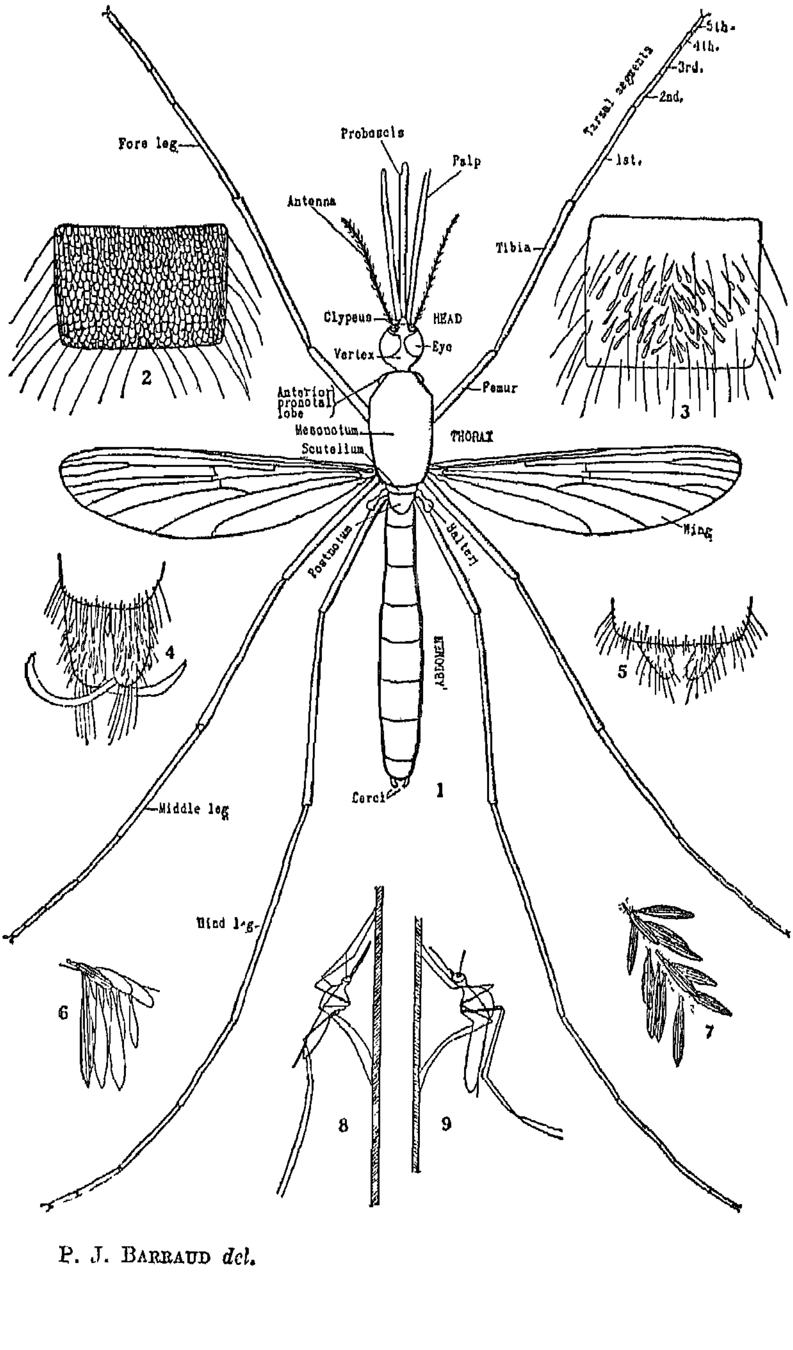
Nos. 2, 3—Second abdominal tergite covered with flat imbricated scales in culicine (2), and with scattered scales and hairs in anopheline (3, *Anopheles maculatus willmori*).

Nos. 4, 5—Terminal abdominal segment of mosquito of *Anopheles subpictus* (4, male; 5, female).

Nos. 6, 7—Arrangement of scales in anopheline mosquito wing (6, along hind margin; 7, on vein).

Nos. 8, 9—Resting-attitude of mosquitoes on vertical surface (8, Anopheles female; 9, Culex female). compare fig. 124.

PLATE I.



P. J. BARRAUD *del.*

tertian malaria, *P. malariae* of quartan malaria and *Laverania malariae* of malignant tertian malaria.

Malarial infections in India are due mainly to benign tertian and malignant tertian parasites in about equal proportions, whereas quartan malaria is responsible for less than 1/10th of the total malaria of the subcontinent. In Burma there is an intense zone of quartan malaria in the northern forests but it is absent from the dry zone and reappears in the wet country to the south. The Andamans have a low incidence of *P. malariae.*

Malaria in India is ordinarily responsible directly for at least 1,000,000 deaths each year and in years of severe regional epidemics there may be another quarter of a million deaths. By its direct and indirect actions it is almost certainly responsible for at least 2,000,000 deaths annually. It is probable that at least 100 million persons suffer from the disease each year and it is probably responsible, through its effects in lowering the vitality of the sufferers, for an additional indirect morbidity of between 25 and 75 millions annually. (Sinton, 1939).

The financial losses caused by malaria are discussed in the section on loss caused by insect pests.

LITERATURE ON CULICIDAE:

The literature on Culicidae and Malaria in the Region is very extensive. Comprehensive and classified bibliographies are given in several of the general reference works quoted below and these should be consulted.

Barraud P. J., 1934, *Fauna Brit. Ind.*, Diptera, v, Culicidae, Megarhinini and Culicini, 463 pp., 106 figs., 8 pls.

Barraud P. J. (Puri I. M.) 1939, *Health Bull.* No. 18, *Malaria Bureau*, No. 9, 2nd revised ed., A practical entomological course for students in malariology. pp. 143, 18 pls., 208 figs. (bibliography).

Christophers S. R, 1933, *Fauna Brit. Ind.*, Diptera, iv, Culicidae, Anophelini, 371 pp., 53 figs. More than 800 classified references.

Covell G., 1927, *Ind. Med. Res. Mem*, No. 5, The distribution of Anopheline mosquitoes in India and Ceylon, 37 maps (bibliography)—1931, *Rec. Mal. Surv. Ind.*, ii, pp. 225, ibid, Additional records, 1926-1930.

Knowles R. and Senior White R., 1927, Malaria its investigation and control with special reference to Indian conditions, 220 pp., 102 figs.

Phillips J. A S., 1929, *Malaria in forest areas.*

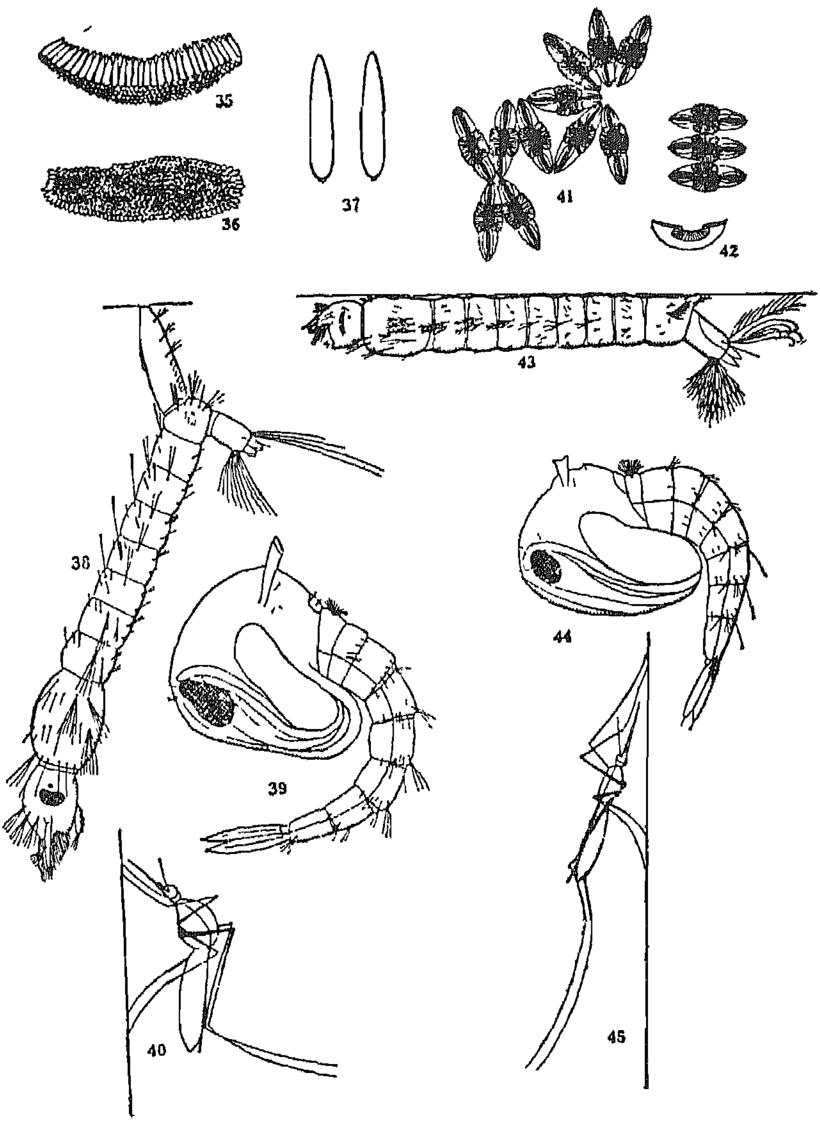
Puri I. M., 1935, *Rec. Mal. Surv. Ind.*, v, p. 265, p. 269, Schematic table for the identification of the Indian Anopheline mosquitoes, Pt I, Adults, Pt. II, Fullgrown larvae—Also, 1938, *Health Bull.* No. 10, *Malaria Bureau*, No. 2, Synoptic tables for the identification of Anopheline

Fig. 124. Eggs, larvae and pupae of anophelines and culicines.

Nos. 35-40—*Culex fatigans*: 35, 36, Egg-raft from side and from above. 37, Eggs separated from raft. 38, Larva in resting-attitude with breathing-siphon touching surface-film of water. 39, Pupa in resting-attitude. 40, Culex mosquito in resting-attitude.

Nos. 41-45—*Anopheles* sp.: 41, Eggs of *Anopheles splendidus* in patterns formed when floating. 42, one egg, boat-shaped. 43, Anopheline larva in resting-attitude parallel with under-surface of water. 44, Pupa in resting-attitude. 45, Anopheles mosquito in resting attitude on vertical surface.

PLATE 4.



P. J. BARRAUD *del.*

mosquitoes in India, 3rd ed., and, *Health Bull.* No. 16 *Malaria Bureau* No. 7, Synoptic tables for the identification of full grown larvae of Indian Anopheline mosquitoes, 3rd ed.
Puri I. M., 1936, *Rec. Mal. Surv. Ind.*, VI, pp. 177. The distribution of Anopheline mosquitoes in India. Additional records, 1931-1935, also, 1936, *Health Bull.* No. 17 *Malaria Bureau*, No. 8, ibid, 2nd ed.
Sinton A., 1939, *Health Bull.*, No. 26, *Malaria Bureau*, No. 13, What malaria costs India, pp. 127 (bibliography).
Senior White R., 1923, *Catalogue of Indian Insects*, Part 2, Culicidae.
— 1927, *Spol. Zeylan.*, XIV, pp. 61-67, The larvae of the common non-anopheline mosquitoes.
Strickland C. and Choudhury K. L., 1927, An illustrated key to the indentification of the Anopheline larvae of India, Ceylon and Malaya.
Williamson K. B., 1935, *Trop. Agr.*, pp. 74-87, The control of rural malaria (1934, *Malayan Agri-horticult. Assoc. Mag.*, IV, 1, 2).

Aedes aegypti, the Tiger Mosquito, is a black and white banded species which may be described as a man-hunting, day-biting mosquito. It is a cosmopolitan species which occurs throughout India but most abundantly in cities and towns, breeding in artificial collections of water near and in human houses such as in *pots, jars, bottles, chatties, tubs, tins, shallow tanks, gutters*, drains and various domestic utensils that collect water during the rains. It is rarely found breeding in natural ponds or wells. The larvae are bottom-feeders but usually rest near the surface of the water.

Dengue fever, which is a widespread disease in India and usually epidemic in the chief ports, is due to a filterable virus and is transmitted by this mosquito. In America *Aedes aegypti* is the carrier of yellow fever, a disease caused by a filterable virus, and the chance that this disease may be introduced to India, while remote, becomes less so with the ever-increasing ease of air-transport. It has recently been found that the common brown monkey, *Macacus rhesus*, and the Indian crown monkey, *M. sinicus*, are both susceptible to yellow fever and therefore capable of forming a reservoir of infection should the disease be introduced to India. Special precautions are taken at air-ports against admission of mosquitoes or infected persons. This species is believed to transmit the filarial disease of elephantiasis (see also *Culex fatigans*). *Stegomyia fasciata* is a synonym of *A. aegypti.*

Aedes albopictus has been shown to be a carrier of dengue in countries outside India. It breeds in tree-holes, bamboos and only rarely in artificial receptacles, nevertheless is very common.

Aedes scatophagoides, a large mosquito, 6 mm., the larvae of which live in open natural pools and are predaceous on other mosquito larvae.

Genus **Anopheles.** The characters by which anopheline eggs, larvae, pupae and mosquitoes can be distinguished from other Culicidae are illustrated in figs. 123 and 124.

M a l a r i a - c a r r i e r s: There are 43 species or 54 varieties of Anophelini or *Anopheles* in India and Ceylon of which 5 are

important malaria-carriers where-ever found: *Anopheles culicifacies*, *A. fluviatilis*, *A. minimus*, *A. stephensi* and *A. sundaicus*. Two other species, *A. philippinensis* and *A. varuna*, are proved carriers in some areas but are less important. Two species, *A. multicolor* and *A. superpictus* are important carriers elsewhere but within the Indian region occur only in Baluchistan and the North West Frontier Province. Twenty species have been found infected in nature or infected experimentally within or without the Indian region but are probably not important as carriers. The extremely common species, *A. subpictus* and *A. vagus*, appear to have little or no relation to the incidence of malaria in India (Christophers).

Life-cycle: Eggs are laid singly on water but they tend to collect together by the action of surface-tension and form patterns. Broad oval eggs with prominent floats tend to cohere in sets of 3, forming triangles or stars or 6-rayed hexagons [fig. 124, No. 41]. Long straight eggs, or those without floats, drift side to side forming straight or curved ribbon-like groups. Hatching takes place in 48 hours. The larval period varies from 8 to 30 days according to temperature and food-supply; in unusual breeding-places, e.g., some kinds of tree-holes, larval life may be prolonged over 5 months. The pupal period is only 2 or 3 days. The total life-cycle from oviposition to adult requires 13-19 days under average tropical conditions; in exceptionally heated sites the cycle may be completed in 9 or 10 days.

Larval food: The larva usually lies at rest at the surface of the water [fig. 124, No. 43] where it feeds by propelling through its mouth a current of water from which the maxillae comb out the food-particles, i. e., unicellular algae, protozoa, bacteria and other floating plant and animal matter (and also any poisonous dust that may be sprinkled on the surface).

Breeding places: *Anopheles* breed in water of very varied character, e.g., in small quantities in vessels or artificial receptacles, puddles and pools to large areas such as swamps, river-margins, rice-fields, brackish waters. Different species show predilection for certain types of breeding-place. The type of country affects the distribution of species. India, being largely cleared of primeval forest and lacking over most of the area the mangrove and *Nipa*-palm swamps of countries further east, is not concerned primarily with the species of such environments. The broad alluvial plains are populated by 'domestic' and rice-field species; the low hill tracts of the Peninsula have a different group of species and the high plateaux of the south and the Himalayas show a special alpine anopheline fauna not usually found below 5,000 feet. A classification of the chief types of breeding-places and their fauna in the Indian area is given by Christophers, 1933, p. 63: and in the Federated Malay States by Gater and Rajahmoney, 1929. See also under species below.

Movements: Adult mosquitoes of the kinds which enter houses and cattle-sheds are usually termed 'domestic' species; those found almost entirely in forest and jungle, which attack man only in their native haunts, are termed 'wild' species. Some species enter houses to feed at dusk but leave before morning in order to shelter in jungle by day. The domestic species do not remain every night in the same rooms but readily change their shelter so that the anopheline population of any particular building is perpetually changing. The distance voluntarily travelled by mosquitoes from their breeding-places in search of food does not usually exceed a quarter of a mile (Christophers) but transportation by strong winds, currents of the upper air as well as by artificial means such as vehicles may convey them for several miles. Salt marsh mosquitoes are said to travel only short distances, $\frac{1}{2}$–$2\frac{1}{2}$ miles, when the population is low, but will throw off an immense number of migrants which fly over much inhospitable territory to 30 miles away, when pressure of population is severe (Headlee). It is not possible to dogmatise how far a mosquito can travel from its birth-place or to define a safety-zone. After a female has fed on blood the ovaries develop rapidly and are mature in about 5 days in the tropics; a shorter time is needed for subsequent batches of eggs to develop. When the ovaries are nearly mature the female digests all the blood in the gut and leaves the feeding-ground to seek suitable places for oviposition. After successful oviposition she may return to the same feeding-ground or find some other.

LITERATURE:

A bibliography is given in Christophers, 1933, *Fauna of British India*, Anophelini.

Anopheles annularis. Not important as a carrier; distinctly a cattle-feeder; breeds in open, vegetation or grass-covered stagnant waters, rice-fields, etc., (previously known as *fuliginosus*).

A. culicifacies. The most important malaria-carrier in India; breeds in clean water of canals, irrigation-channels and pools, leaks and overflows, seepage water, swampy and marshy land, clear rain-pools on grass, borrow-pits, clear slowly running streams and pools, etc.; commoner in regions with a long dry season. The resting attitude of the adult is somewhat Culex-like but the head and proboscis are in a line with the rest of the body.

A. fluviatilis. An important carrier everywhere; breeds in leaks and seepage water, pools in streams and torrents exposed to sunlight.

A. maculatus. One of the most important carriers in the Malay Peninsula, breeds in grassy river-margins, streams, pools, drains, leaks, rice-fields; avoids shade. [fig. 123, No. 3].

A. minimus. An important carrier; breeds in open clear slowly running water, river-margins, flowing drains and channels; avoids muddy or contaminated water and shade.

A. splendidus. A northern Oriental species breeding in ponds, tanks and pools with vegetation, and in jungle streams. It occasionally occurs in houses and is not a malaria-carrier. [Fig. 124, Nos. 41, 42 show the eggs].

A. stephensi. An important carrier in cities and around habitations: breeds in wells, cisterns, garden-tanks, tins and artificial receptacles with fresh water, also in collections of water on earth, pits, ditches, ruts, etc.

A. subpictus. Not a carrier. A domestic species breeding in temporary collections of water, canals, irrigation-channels, pools, leaks, pits, wallows, ditches, cisterns, pots, tins, etc. [fig. 123, No. 4, 5].

A. sundaicus. A notorious carrier in the Andamans and Ganges delta; breeds in brackish water, mangrove swamps not covered except at high tide. (previously known as *ludlowi*).

A. vagus. Not a carrier. A domestic species and cattle-feeder; breeding-habits are similar to those of *subpictus.*

Armigeres obturbans is a vicious blood-sucker attacking man by day and at dusk; it breeds in tree-holes, bamboos, domestic collections of water, often very foul.

Culex fatigans, a pale or golden brown mosquito with dark scaled wings, expanse 3·5 mm. to 4·5 mm., legs dark brown with dark tarsi, is one of the most abundant Indian culicines occurring in all regions upto about 5,000 feet. It breeds in domestic collections of fresh water in such places as flooded open cement drains, flooded latrines, stagnant overflow-water from houses, kitchens, etc., also in ground pools, ditches, shallow wells, rarely in tree-holes or bamboos, not in jungle pools, stream pools, etc., if far from human habitations (Barraud). Almost any water, however foul, will serve as a breeding-ground provided the current is not so swift as to wash the larvae away (Senior White) but stagnant filthy water is especially favoured.

The life-cycle is completed in about a week with a minimum of 4½ days from emergence to oviposition. It is most active during the first two hours of darkness and can fly 2 or 3 miles from its breeding-place. The egg, larva, pupa and resting-position of the adult are shown in fig. 124, Nos. 35-40.

It appears to be the chief carrier of filariasis (*Wuchereria bancrofti*, elephantiasis) and is more infected with filaria in June, July; it is in the monsoon months when the human skin is moist that filariasis is most readily transmitted (see also *Aedes aegypti*).

Culex fuscanus, C. raptor and **C. vorax.** The larvae are predaceous and devour the larvae of other mosquitoes, chiefly *Culex fatigans*; the females seldom attack man.

Mansonia annulifera, a common yellowish-brown mosquito which is a troublesome biter and a transmitter of filaria in India; it breeds in ponds and swamps overgrown with vegetation.

Megarhinus splendens, the largest Indian species, wing 8·5–9 mm., is not a blood-sucker; its larva is predaceous.

ITONIDIDAE

GALL-MIDGES or gall-gnats comprise a nemocerate family of over 3,000 species of slender soft-bodied flies ranging from 0·5–8 mm. in length [fig. 125]. The ITONIDIDAE (or Cecidomyidae) lay eggs on various kinds of plants and the attack of the minute apodous larvae which hatch out results in the formation of excrescences or galls. The larvae derive shelter and nourishment from the distorted tissues; most species pupate inside the gall. Many species of midges do not make galls and many live on decaying vegetable matter. Some species are entomophagous predators attacking other midges, coccids, aphids and psyllids and mites. The systematics of the family have been studied in India by M. S. Mani.

LITERATURE ON ITONIDIDAE:

Brunetti E., 1920, *Rec. Ind. Mus.*, XVII, pp. 8-18, 267-271, Catalogue of Oriental and South Asiatic Nemocera.

Felt E. P., 1920, 1922, *Mem. Dept. Agr. Ind.*, Ent., VII, pp. 1-11, 15-22, 23-28, New Indian gall midges. — 1926, *tit. cit.*, IX, pp. 241-245, *ibid.* — 1929, *tit. cit.*, X, pp. 1-4, *ibid.*

Ghosh C. C., 1921, *Rep. Proc. 4th Ent., Meet.*, Pusa,. p. 115, Life-history of the paddy gall-midges.

Mani M. S., 1933, *Curr. Sci.*, II, pp. 146-147, Plant galls as natural checks to wild vegetation.

— 1934, *Rec. Ind. Mus.*, XXXVI, pp. 371-451, figs. 28, pl. i, Studies in Indian Itonididae (bibliography). — 1935, *tit. cit.*, XXXVII, pp. 425-454, figs. 14, *ibid.* — 1937, *tit cit.*, XXXIX, pp. 281-286, *ibid*, IV.

Rao Ramachandra, 1917, *Journ. As. Soc. Beng.*, n. s., XIII, p. 2, Notes on some south Indian Cecidomyidae causing galls in grasses.

Senior-White R., 1922, *Mem. Dept. Agr. Ind.*, Ent., VII, pp. 83, 107, Notes on Indian Diptera.

— 1928, *Cat. Ind. Insects*, pt. 15, pp. 1-23, Cecidomyidae.

Sundar Raman A. H., 1924, *Journ. Ind. Bot. Soc.*, IV, pp. 1-17, 35-49, A contribution to the study of Indian Zoocecidia. A summary of available information on insect and mite galls.

Asphondylia lantanae, the lantana gall-midge. This gall-midge is a small dusky fly of nocturnal habits. The young flower-buds of *Lantana aculeata* are pierced by the ovipositor and the eggs are deposited among the pollen-sacs inside the buds. The maggot feeds on the pollen and adjacent tissues and causes the formation of a gall which resembles a large unopened flower-bud with a bulging swelling on one side. Pupation occurs inside the gall. The attacked flowers do not produce fruits. The species occurs mainly in the hilly tracts of the south of the Indian Peninsula and the western Ghats. In Coorg *Lantana indica* is also attacked. It may destroy large percentages of flowers of *L. aculeata* and inhibit seed-production but it is heavily parasitised by braconids and chalcidoids; it is a species that may possibly be worth introducing to other parts of India in a general scheme for control of lantana by insects.

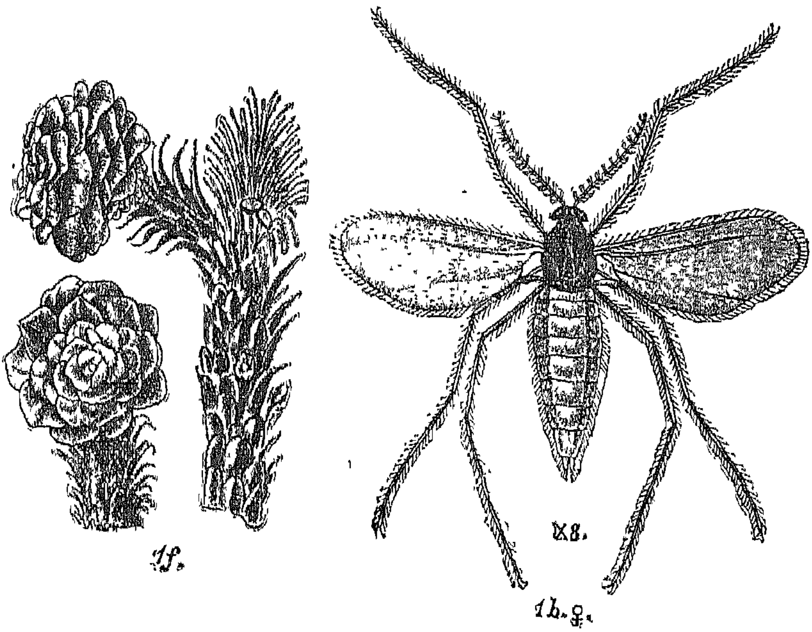


Fig. 125. False cone-galls formed on Pinus longifolia by an undescribed species of Itonididae. 1 *f*, full-grown, opened galls with 2 cocoons of the midge, natural size. 1 *b*, pine gall-midge, female, wing-expanse 6-7 mm.

Asphondylia morindae breeds in the flower heads of *Morinda tinctoria*. Each flower develops into a large, fleshy, globose gall, making a cluster of eight or more semifused galls resembling a fruit. Solitary galls affecting one or two flowers in the inflorescence also occur. The life-cycle is nearly three months (eggs 2 or 3 days, larva 2½ months, pupa 9 days). The gall is figured by Mani in *Rec. Ind. Mus.*, 1934, XXXVI, pl. vii, fig. 2.

Asphondylia phyllanthi makes shiny globose galls on the leaves and shoots of *Phyllanthus emblica*. **A. pongamiae** makes globose galls 1-2 mm. in diameter on the flowers of *Pongamia glabra*. **A. trichocecidarum**, 1 mm., forms hairy globose galls about 3 mm. diameter on the secondary rachis on the pinna of leaves of *Acacia leucophloea*. **A. utriculae** makes bladder-like galls on the ovary of *Dichrostachys cinerea*.

Cecidomyia dattai makes univalve galls on the leaflets of *Aegle marmelos*.

Cecidomyiella crataevae forms leaf bud galls on *Crataeva religiosa*. Eggs are laid on leaf-buds and hatch in 2 or 3 days. The larval period in the galls is about 2 weeks. The red larvae

emerge from the galls and fall to the ground and pupate below the soil-level in silk-lined chambers. The pupal period is 3 days. There are several generations. The gall is figured by Mani, 1934, *Rec. Ind. Mus.*, XXXVI, pl. vii, figs. 4, 5.

Colpodia dhakae, 1·5 mm., feeds under the decaying bark of *Butea frondosa* maturing in November–March.

Diadiplosis indica is predaceous on the scale insects, *Phenococcus* spp.

Horidiplosis fici and **H. mathuri,** 2 mm., make pustular galls on leaves of *Ficus infectoria* and *F. glomerata* respectively.

Lasioptera trilobata make galls on *Schima wallichii*.

Meinertomyia aequipalpis, 1 mm., breeds under the decaying bark of *Ficus rumphii*. **M. inaequipalpis,** 0·75 mm., breeds under the bark of *Buchanania latifolia*, *Lannea grandis*, *Morus alba*, *Polyalthia simiarum*, etc., flies emerging in September, December.

Microdiplosis pongamiae, 1 mm., is associated with a mite, *Eriophyes cheriani*, in the formation of hollow polypoid pedicelled galls on the upper surface of leaflets of *Pongamia glabra*. There are several generations a year

Microspatha tamaricis, 2·7 mm., occurs in galls on *Tamarix dioica*, which are globose, hard, woody growths, 5 10 mm., in diameter, formed on thin twigs.

Myricomyia pongamiae, 2 mm., makes large woody galls on the shoots, rachides and midribs of leaves of *Pongamia glabra*. There appear to be two generations a year.

Neolasioptera crataevae, 2 mm., attacks the young flower-buds of *Crataeva religiosa* and gives rise to large woody galls, 20–30 mm. in diameter. Eggs hatch in a day or two and the larval period lasts two months. Pupation takes place in the galls and the pupal period lasts 15 days. There appears to be only one generation a year. The galls are figured by Mani in *Rec. Ind. Mus.*, 1934, XXXVI, p. 400, fig. 11.

Odinadiplosis odinae, 3·5–4 mm., causes cell-proliferation and tumescence in the cortex of the veins and rachides of leaves of *Lannea grandis*. The life-cycle is—egg 2 days, larva 4 5 weeks, pupa 10 days. Mani, 1938, *tit. cit.*, XXXVII, pp. 436–439, figs. 8, 9.

Pine bud gall-midge. An undescribed species [fig. 125] makes a rosette gall or false cone at the terminal buds of shoots of *Pinus longifolia*. Eggs are laid in the axils of scales of the dormant bud. The growth of the shoot is prevented ; the needles are converted into thickened dwarf scales around an axis $\frac{1}{4}$ to $\frac{1}{2}$ an inch long, forming a conelike structure of solid green resinous tissue in which the midge larvae feed. In autumn the galls are $\frac{3}{4}$ to 1 inch long and in November the cone-scales separate, curling outwards and downwards [fig. 125, 1 *f.*]. The yellow larvae, 5·6 mm., leave the gall and crawl on to an adjacent shoot

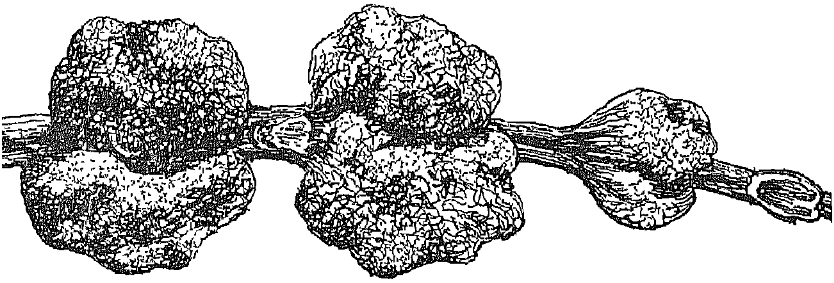


Fig. 126. Multilocular galls formed on stem of Tectona grandis by an undescribed species of Itonididae; natural size.

and pupate in cocoons among the bases of the needles or scales.

Stebbing, 1911, *Ind. For. Mem.*, Zool., II. ii, pp. 30-33, pl. xxii (as Cecidomyia sp.).

Pruthidiplosis mimusopsicola, 3-4 mm., attacks the flower buds of *Mimusops hexandra* and prevents the formation of normal fruits. Instead fruit-like corticose galls, i.e., galls with a spongy inner substance and a hard shell-like outer rind, are produced. When the galls mature the sclerodern dehisces exposing the pupae and thus facilitating the escape of the midge.

Schizobremia malabarensis breeds on the mealy bug, *Pseudococcus virgatus*.

Schizomyia acaciae, 1 mm., lays eggs on the tender buds of *Acacia leucophloea*. Larvae hatch on the third day and lie between two minute, closely applied leaflets adjacent on the same side of the pinna and absorb nourishment from them. This causes cell-proliferation in the two leaflets which swell near the base and fuse together. Tomentum appears on the surface of the gall in about a week. The larval period is about two months. Before pupating the larva bores a hole to the exterior. Pupation occurs inside the gall and the pupa matures in 5 days. There appear to be two generations a year.

Mani, M. S 1934, *Rec. Ind. Mus.*, XXXVI, pp. 406, 407, pl. vii, fig. 1.

Teak stem gall-midge. An undescribed species attacks the new shoots of *Tectona grandis* and causes the formation of a globular multilocular gall which envelops the stem and varies in size by coalescence from ½ an inch to 2½ inches in diameter. [fig. 126]. During the course of the growth of the shoot the gall increases in size and hardens and finally becomes woody. The life-cycle of the fly is annual with emergence in the spring when the new growth of the host-tree begins. This pest is abundant in poor class teak forest and plantations in Central India and Coorg where it seriously affects the growth of teak.

MUSCIDAE

IN the restricted modern sense the MUSCIDAE contain houseflies and non-biting blood-sucking muscids and true biting blood-suckers. The species mentioned below are all oviparous with larvae [fig. 127] living in decomposing animal or vegetable refuse. The genus *Glossina*, the tsetse flies, does not occur in India; a note on the silvicultural control of the tsetse fly in Africa is given in Part Two.

The blowflies and the sarcophagid flesh-flies are combined in the family Calliphoridae.

LITERATURE ON MUSCIDAE:
Patton W. S. and Cragg F. W., 1913, A textbook of medical entomology.
Senior White R., 1920, *Spol. Zeylan.*, XII, pp. 294-314, The Muscidae testaceae of the Oriental Region.

There are about 30 species of **Musca** in the Oriental Region, differing slightly in size, colour, markings, structure and habits, but easily mistaken for and frequently dismissed as "just an ordinary common housefly". They can be assigned to 3 biological groups: *(a)* House, bazaar and camp frequenting species, *(b)* Haematophagous species (only of veterinary importance), *(c)* Blood-sucking species *(Philaematomyia)*. Flies of groups *(a)* are carriers of bacteria such as *Bacillus typhosus* (typhoid fever), the vibrio of cholera, bacteria and protozoa of diarrhoea, dysentery, diseases of the eye, etc. Infection of food is caused by the fly by means of simple mechanical contamination, or by faecal droppings, or by the vomit-drops of regurgitated food.

The eggs are laid and the larvae feed chiefly in horse manure, human excrement, in fermenting or rotted vegetable matter, flesh, meat, offal, farinaceous food-stuffs, etc. The mature 3rd stage larva leaves the food-material and buries itself in soil for pupation. The fly which emerges from the puparium can push its way through several inches of soil.

The life-cycle varies in length considerably with temperature; in hot regions eggs hatch in 6–8 hours, the larval stage [fig. 127] lasts 3 or 4 days, pupal stage 2 or 3 days. In arid regions where the night temperature is high the life-cycle can be completed in 5 days. A female *Musca* lays large numbers of eggs; over 2,300 eggs in the course of 31 days is quoted as the record and is perhaps exceptional. It is evident that a short life-cycle combined with high fecundity and a concentration of breeding material can rapidly produce a plague of flies.

For further details of the life-history and hygienic importance of houseflies the pamphlets and posters of the local public Health Authorities should be consulted.

Patton W. S. and Senior White R., 1924, *Rec. Ind. Mus.*, XXVI, pp. 553-577, 14+53 figs. on pls., The Oriental species of the genus Musca Linnaeus.

Musca crassirostris is one of the commonest blood-sucking flies *(Philhaematomyia)* in India, Burma and Ceylon; the fly is

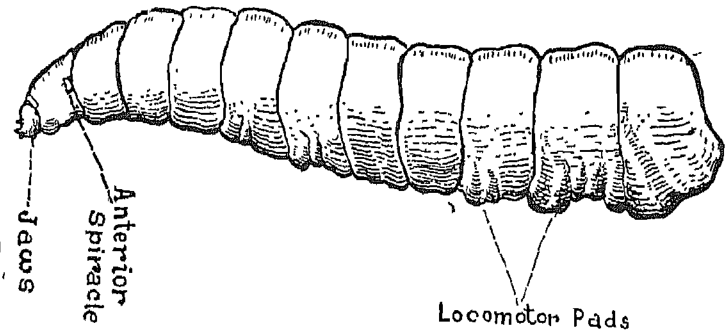


Fig. 127. Larva of Musca vicina, 10 mm.

able to scratch the skin of an animal and draw blood.

M. domestica, the housefly of temperate regions, characterised by broadly separated male eyes, occurs at a few localities of high elevation in the palaearctic districts of India. It is represented in the tropics and subtropics by *M. vicina*.

M. nebulo, widespread in the Orient and a common bazaar and house fly (which rarely breeds in cowdung).

M. planiceps, throughout India and Ceylon, a blood-sucking species feeding on cattle.

M. sorbens, of the Mediterranean, Ethiopian and Oriental Regions, is one of the most widely distributed subtropical and tropical house, bazaar and camp flies breeding in cow and horse-dung, human excrement, etc. It is persistent in attempts to settle on perspiring skin, sores, discharges from the eyes, etc. and is an important carrier of the bacteria of eye-diseases (*angustifrons* is a synonym).

M. vicina, a house-frequenting fly and one of the commonest and most widely distributed oriental flies. The male is distinguishable from the male of *domestica* by its narrower front; it does not breed in cowdung [fig. 127, larva].

M. yerburyi, a bazaar fly in south India. **M. xanthomelas**, widely distributed in India.

Passeromyia heterochaeta. The larvae live in the nests of wire-tailed swallows; at first they feed on the debris and feather-dust of the young nestlings but later on they bore into the flesh of the birds' body eventually killing them. Pupation takes place in the nest.

Patton W. S., 1921, *Ind. Journ. Med. Res.*, VIII. pp. 30, 31, fig. 4.

Stomoxys calcitrans. The Stable Fly, a true blood-sucking fly with a long proboscis formed as a piercing organ, which attacks human beings and cattle. It breeds in horse manure and stable bedding soiled with urine, soil rich in organic matter, fermenting grass, etc.

OESTRIDAE

FOREST Officers who may have to deal with botflies or warbles in elephants (**Cobboldia**) or in grazing and draught animals, cattle, sheep, goats, horses, etc., (**Gasterophilus**, **Hypoderma**, **Oestrus**) will find the following literature useful:—

Brunetti E., 1923, *Fauna Brit. Ind.*, Diptera, III, pp. 383-404.

Fletcher T. B. and Sen S. K., 1930, *Journ. Cent. Bur. Anim. Husb. Dairy. Ind.*, IV, pp. 1-5, 127-138, pls. i-iii, x-xiv, A veterinary entomology for India, The Oestridae.

Bhatia H. L., 1934, *Agric. Live-stock Ind.*, IV, pp. 516-523, pl. i, The bot flies of goats and sheep.

Russell H., 1922, *Journ. Bomb. Nat. Hist Soc.*, XXVIII, pp. 703-718, figs., On Indian parasitic flies.

Sen J. K., 1934, *Agric. Live-stock Ind.*, IV, pp. 189-196, pls. 3, The ox warble fly.

Soni B. N., 1940. *Ind. Journ. Vet. Sci.*, X, pp. 280-283, Preliminary observations on the bionomics of the goat warble fly.

OSCINIDAE see CHLOROPIDAE

PSYCHODIDAE

VERY small fragile moth-like flies with wings hairy (or in a few forms, also scaly) held roof-like over the body as in moths or divergent as in butterflies (*Phlebotomus*). These flies occur in shaded and damp places; the larvae feed in decaying vegetation, dung, damp stony soil. A few species, which are blood-suckers and possible disease carriers, are all included in the genus *Phlebotomus* and are termed Sandflies (because some of the species occur typically in hot, more or less desert regions).

The genus **Phlebotomus**, Sandflies.

Life-cycle: The eggs of *Phlebotomus* are laid in soil in dark places such as under stones, in latrines, and cattle sheds near cesspools, and wells, in caves, and sometimes in burrows of rats, etc. The larva has a large head with well-developed jaws; the body is covered with toothed spines and at the posterior end are two pairs of very long black bristles. The larvae live in the top 2 or 3 inches of soil and apparently they feed on the excreta of lizards, ants, woodlice, insects, etc. The pupa is remarkable for large ridges and excrescences on the thorax. The length of the life-cycle varies from a month in the hot weather to two months in the colder season.

Economic importance: About 33 species of the genus *Phlebotomus* are found in British India, the most widespread sandflies being *Phlebotomus minutus* and *P. argentipes*. Sandflies are a very serious pest to man in India, especially in the Punjab and N. W. Frontier. On account of the small size of many of the species the ordinary mosquito-net is no protection against them. In the hot weather nights they may cause greater annoyance than mosquitoes; in closed and darkened rooms they bite throughout the day also. The bite causes an immediate

burning pain, and the intolerable itching results in so much scratching that abrasions may be formed, which, if infected, may give rise to chronic sores.

Disease-carriers: Three species are believed to be concerned in the carriage of pappataci fever (also called three-day fever, sandfly fever). *Phlebotomus minutus* and *P. sergenti* are responsible for oriental sore. Dengue may be the result of sandfly bites. There is no positive evidence of the transmission of kala-azar by sandflies although *P. argentipes* has been infected with the disease artificially.

Seasonal occurrence and distribution: As a rule sandflies are very local in their occurrence within the areas in which they are found, the localisation often being restricted to certain spots, buildings, or even rooms in buildings. Sandflies have limited powers of flight and probably do not travel far from their breeding-grounds. On windy days, when conditions would be favourable for dispersal, they remain in shelter. Atmospheric conditions affect the prevalence of sandflies and also influence their biting propensities. They occur in greatest number at times of excessive heat combined with high relative humidity. In the northwest regions of India, where the winter temperatures are very low, they may be absent for some months at this season, and again may diminish in numbers during the hot dry months of summer. The periods of great abundance are in April and May and again in August and September. In regions to the south and east where the climate is moister and more equable, they may occur throughout the year. In northwest India they are most abundant at the end of September and early October.

For control measures, see Part Two.

Brunetti, E., 1912, *Fauna Brit. Ind.* Diptera, Nematocera, pp. 196-257, figs. 26-36.

Sinton J. A., 1924-1933, *Ind. Journ. Med. Res.*, XI-XXI, Notes on some Indian species of the genus Phlebotomus, Parts 1-36.

Tonnoir A. L., 1933, *Rec. Ind. Mus.*, XXXIV, pp. 53-75, Descriptions of remarkable Indian Psychodidae and their early stages with a theory of the evolution of the ventral suckers of dipterous larvae.

SARCOPHAGIDAE see CALLIPHORIDAE

SIMULIIDAE

ONLY one genus, **Simulium**, which is composed of about 12 Indian species of blood-sucking Potu Flies,—or socalled sandflies—the females of which bite viciously both man and beast, producing inflamation of the skin which readily turns to sores if scratched and made septic. The larvae are aquatic living usually in mountain streams, in the stems of water-plants (*Phellandrium*, *Sium*, etc.) or attached by the tail-end to rocks covered by swiftly running water, their bodies being held vertically. Their food consists of diatoms, desmids, etc. Pupation

takes place in a membranous cocoon fastened to the stem of a plant. The pupal skin gradually gets distended with air and when it splits a bubble of air is released; the bubble carries the fly to the surface of the water over which the dry fly can run to terra firma and expand its wings in safety. For control see Part Two.

Brunetti E., 1912, *Fauna Brit. Ind.*, Diptera Nematocera, pp 182-195, figs. 22-25.

Simulium indicum, 2-2·5 mm., is the potu fly of the Himalayas up to 10,000 feet. The main period of emergence is April - June, beginning in February in the valleys and disappearing with the rainy season. The bite is painless and unnoticed but is followed by the formation of a small blood-clot and an intense irritation.

S. striatum in south India and Ceylon.

STRATIOMYIDAE

LARVAE of the family STRATIOMYIDAE are frequently found under the bark of logs, in decomposing wood and rotting fruits and vegetable matter generally; the subcortical forms are elongated, flattened and leathery. Other forms of larvae living in wet soil, dung or semi-liquid matter are 'rat-tailed' like those of *Eristalis* (Syrphidae). It is probable that the wood-dwelling species are carnivorous or predaceous. The life-cycle is annual or prolonged to a second year.

Brunetti E., 1920, *Fauna Brit. Ind.*, Diptera Brachycera, I, pp. 17-100, figs.

— 1923, *Rec Ind. Mus.*, XXV, pp. 45-175, Second revision of the Oriental Stratiomyidae.

Flies of the following species have been bred from caged logs of Indian trees. **Acanthina argentihirta** from *Acacia arabica*. **Acraspidea felderi** from *Bombax malabaricum*. **Aulana sumatrana** from *Hodgsonia heteroclita* in Burma. **Burmabrithes annulipes** from *Millettia pendula* in Burma. **Clitellaria heminopla** from *Carica papaya* and *Moringa pterygosperma*. **Wallacea argentea** from *Ficus carica*, *Garuga pinnata* and *Shorea robusta*.

SYRPHIDAE

SUNLOVING flower-haunting flies, very swift on the wing and expert hoverers, the SYRPHIDAE are popularly known as Sun Flies or Hover Flies. The larvae are practically all predators and live in diverse environments, viz., (*a*) freely on foliage feeding on aphids and other homoptera (*Baccha*, *Syrphus*, *Xanthandra*), (*b*) in decaying wood or bark or in wounds in the same (*Ceria*, *Helophilus*), (*c*) in water or semi-liquid decaying organic matter (*Eristalis*).

LITERATURE ON SYRPHIDAE;

Bhatia H. L. 1931, *Ind. Journ. Agr. Sci.*, I, pp. 503-513, pls. LVI-LVIII, Studies in life-histories of three Indian Syrphidae.

Bhatia H. L. and Mohammad Shafi, 1933, *Ind. Journ. Agri. Sci.*, II, vi, pp. 543–570, pls. LX–LXVIII, Life-histories of some Indian Syrphidae.
Brunetti E., 1923, *Fauna Brit. Ind.*, Diptera, III, pp. 23-339.
Cherian M. C., 1934, *Journ. Bomb. Nat. Hist. Soc.*, XXXVII, pp. 697-699, Notes on some south Indian syrphids.
Curran C. H., 1928, *Journ. F. M. S., Mus.*, XIV, pp, 141-324, pls. iii, iv, 12 figs , The Syrphidae of the Malay Peninsula
Rahman K. A., 1940, *Proc. Ind. Acad. Sci.*, XII. B, pp. 71-72.

Asarcina aegrota and **Ischiodon scutellare,** are commonly predaceous on Aphidae.

Baccha pulchrifrons, widespread in India, is predaceous on the nymphs of *Apsylla cistellata*, *Cerotrioza* sp., *Phylloplecta malloticola*, and *Tenaphalera acutipennis* (Psyllidae). The eggs are laid singly on leaves and hatch the next day. The larva, 8·5 mm. long when fullgrown, feeds on the young psyllid nymphs, sucking up the body-fluids, a process which is complete in one or two minutes. A larva of *Baccha pulchrifrons* may kill 60 psyllids in the course of an hour; and it is presumably responsible for the death of thousands of nymphs during its larval life which lasts 12 to 14 days. The pupal period is about 11 days giving a total life-cycle of 3½ weeks.

Bhatia H. L. and Mohammad Shafi, 1932, *Ind. Journ. Agr. Sci.*, II vi, p. 549 pl. lx.

Baccha saphirina is also predaceous on psyllids.

Ceria eumenoides is a wasp-like syrphid with porrect antennae. The larva, 25 mm. long, feeds in the sap of *Albizzia lebbek* fermenting in holes in the bark or in wounds. The egg hatches in 2 days, the larval stage lasts 13 weeks, the pupal stage 2 weeks, total life cycle 16 weeks. All instars are described and figured by Bhatia, 1931, *tit. cit.*, I, pp. 503–508, pl. lvi (coloured).

Eristalis quinquestriatus. The larva lives in stagnant water full of decomposing organic matter, on the edges of swamp and marsh and in dirty drains; it is of the 'rat-tailed' type, that is, the last three abdominal segments are elongated into a slender telescope-like tail. The full-grown larva is 15 mm. long and 3·5 mm. broad; the tail is 35 to 40 mm. long when fully extended and in use as an air-supply tube. The pupa also retains a long tail. The whole life-cycle takes 20 days (egg 1 day, larva 10–12 days, pupa 7 days). The stages are described and figured by Bhatia, 1931, *tit. cit.*, I, pp. 508 510, pl. lvii.

Eumerus aurifrons breeds in the fermenting sap and muck in wounds on *Albizzia lebbek* and other trees.

Heliophilus bengalensis breeds in wet fermenting woody pulp and the larva feeds on the maggots of other species of Diptera living in it; it is 'rat-tailed' as in *Eristalis*, 3·5 mm. when full-grown, with a tail about 7 mm. long; the pupa is also tailed. The life-cycle takes about 3 weeks.

Bhatia H. L and Shafi M., 1932, *Ind. Journ. Agr. Sci.*, II, pp. 567-569, pl. lxvii (coloured).

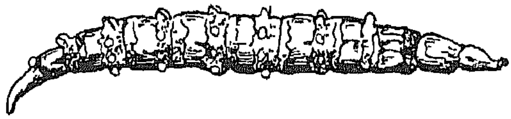


Fig. 128. Larva of Tabanus, 20 mm.

Helophilus curvigaster breeds in holes in trees in which wet vegetable matter is putrefying. The larva and pupa are "rat-tailed". The larva feeds on maggots of other species of Diptera which live in the decaying matter. The life-cycle lasts 5 weeks.

Bhatia, 1931, *tit. cit.*, I, pp. 510-513, pl. lviii (coloured).

Paragus serratus is predaceous on *Euphalerus vittatus* (Psyllidae) on Aphidae. The life-cycle lasts about 2 weeks.

Bhatia and Shafi, 1932, *tit. cit.*, II, pp. 555-556, pl. lxi.

Sphaerophoria indiana, a common species in Western Himalayas and plains, has a short life-cycle of 12 days (larva 7 days, pupa 4, 5 days) in the Punjab; a larva can eat 40-60 aphids a day (Rahman, 1940).

Sphaerophoria javana is predaceous on *Phyllopleeta* sp., a psyllid making pit-galls on the leaf of *Shorea robusta* and *Psylla* sp. on *Bauhinia variegata* and *Tenaphalera acutipennis* (Psyllidae). The life-cycle takes about 3 weeks.

Bhatia and Shafi, 1932, *tit. cit.*, pp. 557-559, pl. lxii.

Syrphus balteatus, a common hoverfly throughout India, is predaceous on aphids and coccids. The larva hatching from an egg laid on a leaf, wanders about on the foliage, feeding on aphids and nymphs of coccids for 10-14 days; one larva may eat 15 to 50 aphids a day. The pupal period takes about 9 or 10 days and the whole life-cycle lasts 3 weeks.

Bhatia and Shafi, 1932, *tit cit.*, II, pp. 561-565, pl. lxiv.

Syrphus confrater, S. serarius and **S. transversus** are other species feeding on aphids in the hills and the plain.

Bhatia and Shafi, 1932, *tit. cit.*, pp. 559, 565, pls. lxiii lxv.

Xanthandrus indica. The larva of this hoverfly feeds on young caterpillars of *Hyblaea puera* which it discovers in the folded edges of the leaves of teak or *Vitex negundo*. One syrphid may eat 2 or 3 small caterpillars daily. The puparium is formed on the leaf and fly emerges in seven days (in August).

TABANIDAE

HORSEFLIES or Gadflies are the names commonly given to the large biting and blood-sucking flies of the TABANIDAE in temperate countries; in the Orient they are more notoriously pests of cows, buffaloes, camels and elephants, and not only because of the worry and ill health caused to domestic animals in general but because some species are probable carriers of surra.

There are about 150 species listed in the Indian region out of a world total of 2,000.

LITERATURE ON TABANIDAE:

Fletcher T. B. and Sen S. K., 1931, *Ind. Journ. Vet. Sci. An. Husb.*, I, pp. 192-199, pl. (coloured) A veterinary entomology for India, XIV.

Isaac P. V., 1925, *Mem. Dept. Agr. Ind.*, VIII, pp. 93-109, Papers on Indian Tabanidae.

Senior White R., 1922, *Mem. Dept. Agr. Ind.*, Ent., VII, 9, pp. 103-107, 143-148, Notes on the Tabanidae in the collection of the Forest Zoologist, pls. xi, xii.

— 1927, *Catalogue of Indian Insects*, Part 12, Tabanidae.

Haematopota beesoni, a Burmese blood-sucking fly, attacks elephants and also men who have been riding elephants and still smell of elephant.

Haematopota roralis is a widely distributed and common fly, the female of which sucks the blood of cattle. It breeds in paddy-fields and tracts of water with an inlet or outlet flow. Eggs are laid in masses on the blades of grasses at the edges of channels and the larvae [fig. 128] on hatching drop into the water and burrow into the soil. They feed on small aquatic animals. The life-cycle comprises an egg stage of 4 days, larval stage of 5–7 weeks and a pupal stage in the soil of about 8 days. There are 3 generations a year with flies appearing from April–October, and in greatest abundance in July–August. Hibernation takes place in the larval stage and may extend for 8 months.

Isaac P. V., 1932, *Ind. Journ. Vet. Sci. An. Husb.*, II, ii, pp. 278-280, pl. xxiii, The life-history of Haematopota roralis.

Tabanus speciosus. The female fly sucks the blood of cattle. Eggs are laid on the stems of plants growing in shallow water, in collections of about 500 eggs packed in a globular mass that appears black with white streaks. The larvae [fig. 128] on hatching in 4 or 5 days drop into the water and swim to the water's edge where they burrow into the mud. They feed on earthworms and other soft-bodied organisms in the wet soil. Larvae may mature in about 4 months, or if hatched from eggs late in the year may require six months, hibernating during the coldest season. The pupal stage, passed in the soil, lasts about 18 days.

Isaac P. V., 1933, *Ind. Jour. Vet. Sci. An. Husb.*, III, ii, pp. 182-184, pl. xiii, The life-history of Tabanus speciosus.

TACHINIDAE

FLIES of this family are thickset and conspicuously bristly with the bristles on the abdomen often spine-like [figs. 129, 132]; they frequent flowers and rotting organic matter for food. The larvae of all species of TACHINIDAE are uniformly parasites and almost exclusively on insects. Larvae of the Lepidoptera and to a lesser extent those of the Hymenoptera form the usual hosts, but coleopterous larvae and adult Coleoptera, Orthoptera and Hemiptera are also attacked. Recent biological studies have

extended our knowledge of the hosts and distribution of Indian species which are being increasingly used for biological control of forest insects (see references to literature).

L i f e - h i s t o r y : Females of Tachinidae are either oviparous or larviparous, i.e., the egg may be deposited as soon as fertilised, or may be retained until the embryo is almost completely developed, or may hatch to a larva which is deposited alive. Fertility is extremely high, varying from several hundreds to over two thousand eggs per individual.

Five different methods of egg-production may be distinguished, viz., (1) Host-oviposition, (2) Leaf-oviposition, (3) Supracutaneous host-larviposition, (4) Subcutaneous host-larviposition, (5) Leaf-larviposition.

(1) Host-oviposition: The thin-shelled sometimes stalked egg is laid by the female on the skin of the host-caterpillar. The maggot hatches out after a few minutes to a few days and bores into the body of the caterpillar, e.g., *Eutachina*, *Exorista*, *Sturmia*, *Winthemia*.

(2) Leaf-oviposition: The unusually minute egg is deposited on the food-plant of the host and is swallowed when the food is eaten. The egg hatches almost immediately in the alimentary canal and the maggot bores into the body-cavity of its host, e.g., *Podomyia*.

(3) Supracutaneous host-larviposition: The living larva is deposited on the skin of the host-caterpillar and by means of its already well developed mouth-hooks bores through the skin.

(4) Subcutaneous host-larviposition: The female has a special development of the ovipositor or abdomen by which the host is stabbed and the larva inserted through the the wound, e.g., *Compsilura*.

(5) Leaf-larviposition: The larva is deposited on the food-plant fixed in a membranous cup and awaits the passing of its host near enough, whereupon the tachinid maggot attaches itself by the mouth-hooks and bores in, e.g., *Carcelia*.

In the case of host-oviposition or host-larviposition the caterpillar may moult its skin before the tachinid larva has bored in.

L a r v a : The tachinid larva is usually ellipsoidal to cylindrical, tapering rapidly at the head end, indistinctly segmented and sometimes flattened below; the mouth-parts are solid hooked pieces of chitin; the posterior spiracles are large and strongly chitinised. Air is breathed at some stage in the life within the host by means of a perforation in its body-wall or by means of a secondary connection with the tracheal system of the host. The parasitic larva feeds at first on the blood, fat-body, etc., leaving unharmed the vital organs of its host until the last and may complete its development without killing the latter although its internal organs have been almost wholly liquified. When full-grown the parasite breaks through the skin (which is almost all

that remains of the abdomen of the caterpillar) and usually buries itself in the soil to pupate. In some species the puparium may be formed in the empty skin of the dead host or in the cocoon or pupal skin, if the latter has pupated successfully. Puparia are described in Gardner, 1940. [figs. 130, 133]. Usually one tachinid larva develops inside the body of one host but particularly large caterpillars, *e.g.*, Sphingidae, may support several dozen tachinids.

The duration of the larval stage is closely bound up with that of the host; in the case of Lepidoptera with a larval period of 2 or 3 weeks the period of the tachinid is correspondingly shorter, 8 to 15 days, but in the case of long-lived host-larvae the life of the tachinid is proportionately lengthened, maybe to several months; hibernation as a dormant larva within the host may take place when the host hibernates.

The duration of the puparial stage is usually short, 8 to 10 days during the greater part of the year, but in the north and in the mountains hibernation for several months may occur in the puparial stage.

The Tachinidae are markedly polyphagous, the number of alternative hosts known for some species being as high as 60. Hosts of a polyphagous tachinid are distributed in numerous families and are not necessarily confined to one order of insects. Accurate information on host-relationships and distribution depends on accurate identification which is notoriously difficult in the case of the adult. Indian material has been named by Baranov, Bezzi, Curran, Tothill, and Villeneuve.

LITERATURE ON TACHINIDAE:

Ballard E., 1921, *Proc. 4th Ent. Meet.*, Pusa, pp. 67, 68 pls. x, xii, xi, Tachinidae parasitic on Spodoptera mauritia.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent. I, No. 9. On the biology of the Tachinidae.

— 1939, *tit cit.*, v, No. 5, Further Notes on biology of parasites of teak defoliators in India.

Gardner J. C. M., 1940, *tit. cit.*, vi, No. 7, 227-251, 3 pls., 41 figs., The puparia of some Indian Tachinidae,

— 1940, *Ind. Journ. Ent*, The puparia of some Indian Tachinidae (2).

Garthwaite P. F. and Desai M. H., 1939, *tit. cit.*, v, No. 4. On the biology of the parasites of the teak defoliators in Burma.

Russell H. 1922, *Journ Bomb. Nat. Hist. Soc.*, xxviii, pp. 703-718, On Indian parasitic flies.

Actia aberrans, an internal parasite of the larva of *Hapalia machaeralis* (Pyralidae) in Burma. The puparium, 4 mm. long, is described by Gardner in 1941, *Ind. Journ. Ent.*

Actia aegyptia, parasitic on *Earias insulana*, *Laphygma exigua* and *Spodoptera mauritia* (Noctuidae).

Actia hyalinata. An internal parasite of the caterpillars of *Hyblaea puera* (Noctuidae), *Hapalia machaeralis*, *Bombotelia jocosatrix*, *Glyphodes bicolor*, *G. celsalis*, *G. conclusalis*, *Pyrausta celatalis* (Pyralidae), *Dichomeris bisignella* (Gelechiidae), one parasite developing in each host. The life-cycle corresponds

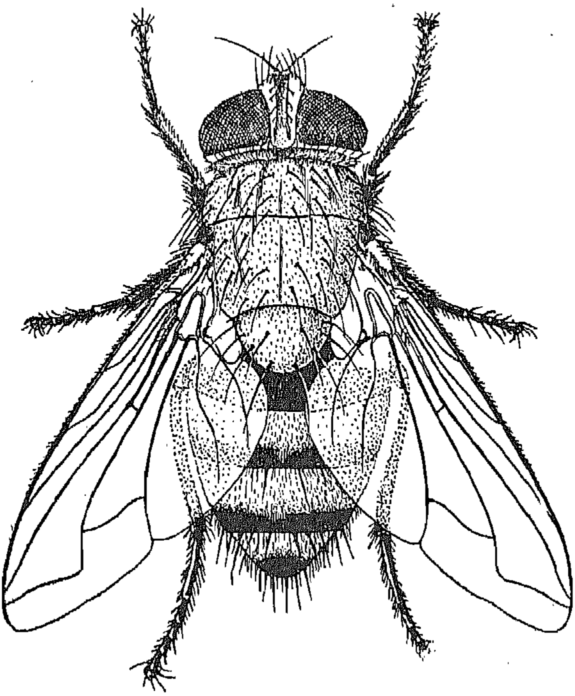


Fig. 129. Carcelia kockiana, 5–10 mm. long.

approximately in length with that of the host, (10 or more days larval feeding-period, 7 to 9 days in puparium in July–September). The puparium, 5 mm. × 2½ mm., is described by Gardner, 1940, *Ind. For. Rec.*, Ent., VI, No. 7, p. 241, fig. 25; the fly is 3¼ to 4 mm. long.

Actia monticola, parasitic on *Laphygma exigua* (Noctuidae).

Alsomyia rufipes on the larva of *Clania crameri* (Psychidae).

Argyrophylax nigritibialis on *Hapalia machaeralis* in south India. The puparium, 4·5 mm., is described.

Bactromyia fransseni, on *Margaronia laticostalis* (Pyralidae), emerges from the winter brood of the caterpillars to pupate in March.

Cadurcia vanderwulpi, on the larvae of *Azinis hilarella* (Hyponomeutidae), *Dichomeris cridantis* (Gelechiidae) and *Hapalia machaeralis*, *Jocara malefica*, *Lamida carbonifera* (Pyralidae). One parasite develops in each host-caterpillar which pupates normally. The puparium, 4 × 2 mm., described by Gardner, 1940, *Ind. For. Rec.*, Ent., VI, No. 7, p. 242, fig. 29, is formed inside the pupa of the host or occasionally in soil and the fly emerges after 7–15 days in April–September. Occurs from

March to September. The maximum recorded parasitism of *Dichomeris eridantis* is 20 percent.

Carcelia buitenzorgiensis on *Diacrisia obliqua* (Arctiidae) and *Euproctis* sp., (Lymantriidae) in India. The puparium, 7×3 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 240, fig. 22.

Carcelia caudata on *Chionaema peregrina* (Arctiidae). The puparium is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 242, fig. 30.

Carcelia kockiana. The hosts of this larvipositing species are *Diacrisia obliqua* (Arctiidae), *Eupterote undata* (Eupterotidae), *Hyblaea puera* (Hyblaeidae), *Hypsa alciphron* (Hypsidae), *Taragama dorsalis* (Lasiocampidae), *Lymantria semicincta* (Lymantriidae), *Achaea janata*, *Fodina stola*, *Sylepta balteata* (Noctuidae), *Margaronia laticostalis*, *Lygropia obrinusalis* (Pyralidae), *Agalope bifasciata* (Zygaenidae) and others. It is widely distributed in the Oriental Region.

Life-history: The adult's life is as long as 33 days; the average is between 5 and 10 days. The female has an egg capacity of 250–300. Incubation takes place inside the body of the female; 7 or 8 days elapse between mating and larviposition. The larva when deposited on or near the host is enclosed in a thin semitransparent case, 1 to 1·5 mm., long; it breaks out in a few minutes and searches for the host-caterpillar and bites its way into the body, connexion with the outside being maintained by a funnel-shaped tube. Normally only one parasite develops in each host which, in the case of *Hyblaea puera*, is attacked in the 4th and 5th instars. The larval period of *C. kockiana* lasts 8 to 10 days; the puparial period 7–13 days in June–September. The average period from the time of mating to emergence of the adult fly is 25 days (range 22–31) which thus closely corresponds to the life-cycle of the host *H. puera* and 13–14 generations a year are possible. *C. kockiana* is tolerant of a variety of hosts and its life-history is modified in conformity with that of the host. When parasitising *Eupterote undata* it has an annual life-cycle, living in the host-caterpillar for about 4 months and remaining dormant in the pupa in the cocoon of *E. undata* throughout the cold and hot weather for seven months, emerging as fly in July. [fig. 129].

Puparia of this species were successfully shipped in cold storage from Burma to Madras and the flies were released in Nilambur in July 1938.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 9, pp. 174, 175, On the biology of the Tachinidae (as *Eucarcelia* (*Senometopia kockiana*).

Garthwaite P. F. and Desai M. H., 1939, *tit. cit.*, V, No. 4, pp. 323-325, fig. 2 (adult), On the biology of the parasites of teak defoliators in Burma.

Gardner J. C. M., 1940, *tit. cit.*, VI, No. 7, p. 245, fig. 38 (puparium as Eucarcelia kockiana).

Carcelia malayana on *Amsacta lactinea* (Arctiidae); the

puparial period is 9 days in August.

Carcella modicella on the caterpillars of *Dasychira cerigoides*, *D. mendosa*, *Lymantria viola*, *L. todara*, *Orgyia turbata*, *Thiacidas postica* and other Lymantriidae. The puparium is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 245, fig. 39.

Carcelia sumatrana on a noctuid defoliating *Sarcosperma arboreum*. The puparium, 7 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 246.

Carcelia thermophila on *Amyna octo*, *Cosmophila fulvida*, *Plecoptera reflexa* and *Tiracola plagiata* (Noctuidae), *Athyma pravara* (Nymphalidae) and *Asota caricae* (Hypsidae). The puparial period is 10 days in May. Two parasites may develop from one host.

Carceliella octava on *Sylepta balteata*, *Hapalia machaeralis*, *Lygropia quaternalis*, and *Pyrausta coclesalis* (Pyralidae); an internal parasite of the caterpillar which pupates and the parasite emerges to form the puparium (decribed by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 244, fig. 35).

Carceliopsis sumatrensis on *Dasychira grotei* (Lymantriidae) and *Stauropus alternus* (Notodontidae). The puparium, 8 mm., is described by Gardner, 1940, VI, No. 7, p. 247.

Chaetexorista javana on *Parasa lepida* (Limacodidae).

Chaetomyobia javana on *Cybolomia nemausalis* (Pyralidae); the puparial period is 11 days, July. The puparium, 6 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 247.

Compsilura concinnata. This species has a wide distribution; in Europe about 60 hosts are known and in North America, whither it was introduced in 1906 and onwards to control the Gypsy and Brown Tail Moths, it has adopted about 30 hosts. In India it occurs from the plains to 7,000 feet in the Himalayas.

Life-history: The eggs hatch in the uterus of the mother and the tiny maggots are deposited beneath the skin of the host-caterpillar by means of a sharp curved larvipositor situated beneath the abdomen (subcutaneous larviposition). About two weeks are required for the growth of the maggot irrespective of the stage of the host at the time of attack and at the end of the period it issues and drops to the ground for pupation. The puparia of maggots that have issued from caterpillars already spun up for pupation remain in the cocoons. The pupal period lasts about a week. Three or four days are sufficient for the female to attain full sexual maturation after emergence. The life-cycle is therefore about 4 weeks. There are 3 or 4 generations annually in temperate climates with hibernation as larva in the host-caterpillar.

In India it has been recorded from *Ectropis deodarae* (Geometridae), *Euproctis bipunctapex* (Lymantriidae), *Hyblaea puera* (Hyblaeidae), *Hypsipyla robusta* (Pyralidae) and a defoliator of *Girardinia heterophylla*.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., 1, No. 9, pp. 172, 173 (bibliography).
Gardner J. C. M., 1940, *Ind. For. Rec.*, Ent., VI, No. 7, p. 243 (puparium).

Cossidophaga atkinsoni on the larva of *Xyleutes ceramica* (Cossidae) in Burma. The puparium [fig. 130, No. 12], 6×2·2 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 237, fig. 12.

Diglossocera bifida on *Anthyma pravara* (Nymphalidae).

Dolichocolon australis on *Plecoptera reflexa* (Noctuidae).

Dolichocolon orbitale. A parasite of *Hapalia machaeralis* and *Pyrausta ochracea*, *Phycodes minor* and other Pyralidae in India. The host-caterpillar is inhabited by a solitary larva and forms its pupa normally. The puparium (5×2 mm.) of the parasite is formed inside the pupal skin of *H. machaeralis* and the fly emerges through a dehiscence similar to that made by the moth. The period passed in the pupa of the host is 11 days in July at which season the normal pupal period of *machaeralis* is 5 days. The total life-cycle of the parasite is equivalent to that of the host, i.e., about 3 weeks. The percentage-parasitism is usually very low.

Beeson and Chatterjee, S. N., 1935, *tit. cit.*, I, No. 9, pp. 173, 174, fig. 1 (adult).
Gardner J. C. M., 1940, *tit. cit.*, VI, No. 7, p. 236, fig. 11 (puparium).

Dolichocolon rufescens on *Polydesma quenavadi* (Noctuidae). This species is known from India and New South Wales.

Erycia bezzii on the caterpillar of *Euproctis bipunctapex* (Lymantriidae). The puparial period, outside the host, is 3 weeks in March.

Erycia nymphalidophaga on *Papilio demoleus* and *P. lankeswara* (Papilionidae). About four parasites mature in one host-caterpillar; the puparial period, outside the host, is 12 to 14 days in October. The puparium, 7 mm., is described by Gardner, 1940, VI, No. 7, p. 247.

Euhapalivora indica on *Hapalia machaeralis* and *Pygospila tyres* (Pyralidae). The puparium, 6 mm., is described.

Eutachina civiloides. The species occurs throughout India and Burma; parasitic on *Hyblaea puera* (Hyblaeidae), *Cirphis unipunctata*, *Fodina stola*, *Polydesma quenavadi*, *Plecoptera reflexa*, *Plusia orichalcea* and other Noctuidae, *Hapalia machaeralis* (Pyralidae), *Psilogramma menephron* (Sphingidae).

L i f e - h i s t o r y: The fly is 8 to 11 mm. long. Eggs are laid on caterpillars in the 3rd and 4th stages (in the case of *Plecoptera*). One mature larva of the parasite (about 8 mm. long) emerges from the full-grown caterpillar or the prepupa or the pupa in which case the puparium is formed in soil, but pupation may also take place inside the host's pupal skin. The puparium is about 6 mm. × 2·5 mm. (described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 244, fig. 36). The puparial period is about

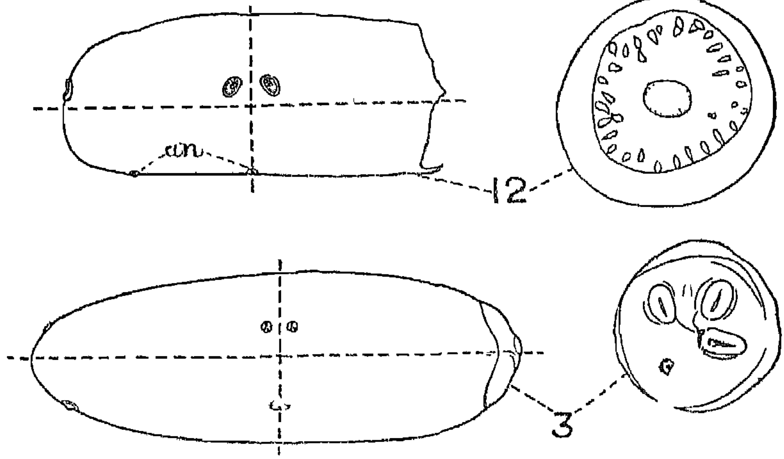


Fig. 130. Puparia of parasites of wood-borers. No. 12 Cossidophaga atkinsoni. No. 3 Myiobia bezziana, (see also fig. 131).

7-10 days in April, May, 6-12 days in June, 7-10 days in July, 6-8 days in August. The adult is active in the cooler period of the morning and afternoon in the sun and partial shade. The species is a regular parasite of *P. reflexa* and *H. puera* but is not very abundant and the parasitism-percentage is low, not exceeding 4 percent. It has been successfully shipped in cold storage from Burma to Madras and transferred by post in the Punjab. It is indigenous from Sind to Madras and Thailand.

Garthwaite P. F. and Desai M. H., 1939, *Ind. For. Rec.*, v, 4, p. 538.
Beeson and Chatterjee S. N., 1939, *tit. cit.*, v, 5, p. 376.

Eutachina fallax. A European species occurring in India and Burma [fig. 132]. Its hosts are *Dasychira mendosa* (Lymantriidae), *Hyblaea puera* (Hyblaeidae), *Plecoptera reflexa*, *Spodoptera mauritia* (Noctuidae) and *Hapalia machaeralis* (Pyralidae).

Beeson and Chatterjee S. N., *Ind. For. Rec.*, Ent. I, No. 9, p. 183 (as *Tachina fallax*) The identification is doubtful.
Garthwaite, P. F. and Desai, M. H., 1939, *tit. cit.*, v, No. 4, p. 339.

Eutachina larvarum. A European species occurring in Kashmir as a parasite of *Lymantria obfuscata* (Lymantriidae). It was one of the first parasites to be imported into the United States for the control of the Gipsy and Browntail Moths. *E. larvarum* is oviparous attaching one or more large conspicuous eggs to the skin of the host and the larva on hatching immediately bores in. The puparia are 6-12 mm. long by 2·5-5 mm. broad. The mature larvae usually leave the caterpillar before it pupates but occasionally emerge from the pupa and the puparium is formed externally. In Europe there are two generations a year with hibernation either as larva within the host or dormant puparium. In Kashmir

flies mature in June, July and require alternative hosts for the monsoon generation.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent. I, No. 9, pp. 175, 176 (references).

Eutorocca fasciata is a dominant parasite of the caterpillar of *Lygropia quaternalis* (Pyralidae) in south India and is common from April to August. The puparium, 7×2 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 238, fig. 18. The maximum monthly parasitism-percentage recorded is 21. (see Beeson and Chatterjee, S. N., 1939, *tit. cit.*, V, No. 5, pp. 364–365).

Exorista grisellina on *Delias eucharis* (Nymphalidae); 5 parasites develop in one host-caterpillar; the puparial period lasts 3 to 8 weeks in December–February. The puparium, 6 mm., is described.

Exorista heterusiae on *Hapalia machaeralis* (Pyralidae) and *Heterusia cingala* (Zygaenidae). The egg is deposited externally on the caterpillar behind the head. The parasitised caterpillar is usually able to spin its cocoon but fails to pupate. Five or six parasites may develop in one caterpillar of *Heterusia*; they emerge to form their puparia inside the coccon of the host. This species maintains effective control of *H. cingala*, the Red Slug of tea in Ceylon.

Hutson, J. C., 1932, *Trop. Agr.*, LXXIX, p. 14.

Exorista picta. A parasite of *Plecoptera reflexa* (Noctuidae) in the Punjab and United Provinces occurring also in Formosa.

Life-history: The female fly (8 mm. long) hovers persistently over foliage of *Dalbergia sissoo* on which *Plecoptera reflexa* larvae are feeding, then swoops suddenly and affixes an egg on the back of the caterpillar behind the head. Usually only one egg is laid on the caterpillar which is generally in the 3rd instar and sometimes the 4th. The egg is elongate-oval, white, shining and hatches in the course of a day and the larva of *E. picta* bores into the body and feeds until the caterpillar pupates. One parasite matures in each host. The puparium is formed either within the pupal skin of the host or, externally in the soil. A parasitised pupa is black with the abdominal segments extended. The larval feeding-period is 12 days and the puparial period 8–10 days in February, March and is 6–8 days and 5–8 days respectively in April–August. The puparium is dark brown, 5 to 7 mm. × 2·5 mm., with indistinct segmentation; it is described by Gardner, 1940, *Ind. For. Rec.*, Ent., VI, No. 7, p. 242, fig. 28. The total life-cycle occupies 12 to 17 days. The flies are active in the early morning and late afternoon preferring partial shade; when searching foliage for caterpillars the fly deposits excrement on each leaf visited. Mating takes place on the first 3 days after emergence. The parasitism-percentage is usually very low in the shisham plantations of the Punjab and rarely rises to 40 percent. In April *E. picta* is scarce but

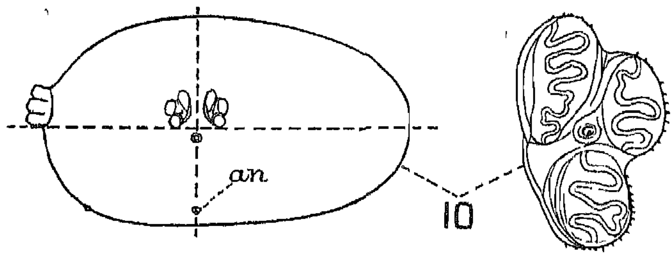


Fig. 131. Puparium of Podymyia setosa, 7 mm. long; the posterior spiracles, wart and anus are shown in relation to the long and vertical axes (dotted); one spiracular plate is enlarged on the right.

increases abundantly during May-July so much that swarms of flies make an audible buzzing. From August onwards the host-population and the parasite markedly decrease.

Exorista quadrimaculata on the bagworm, *Clania crameri* (Psychidae) on *Pinus longifolia*, *Casuarina equisetifolia* and *Shorea robusta*. At least 12 flies mature from one host larva. It is usually evident in April-July. The puparium is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 243.

Gonia cinerascens on caterpillars of *Plecoptera reflexa* and *Spodoptera mauritia* (Noctuidae).

Gymnodexia atkinsoni on a curculionid larva feeding on *Phyllanthus emblica*. It has also been bred from logs of *Bombax malabaricum* attacked by *Dystropicus dorsalis*, *D. clitellae* and *Rhadinomerus bombacis* (Curculionidae).

Hapaliolaemus machaeralis on *Hapalia machaeralis*.

Hemidegeeria villeneuvei has been bred from fruits of *Juglans regia* attacked by *Alcides porrectirostris* (Curculionidae) and is probably parasitic on the weevil larva. It has been bred from fruits of other trees. The puparium, 6×2 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 239, fig. 21.

Macquartia nubilis on the larva of *Chrysolina aurata* (Chrysomelidae). The puparium, 5 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 239, fig. 20.

Masicera oculata on the larva of *Baoris mathias*, *Parnara bada* (Hesperiidae) and *Plusia* sp., (Pyralidae). The puparium, 7×3 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 237, fig. 14.

Masicerella indistincta on a defoliator of *Urena lobata*.

Myiobia bezziana on the larva of *Zeuzera multistrigata* (Cossidae). Up to 6 parasites reach maturity in one host-caterpillar; puparia [fig. 130, No. 3] are formed in the tunnel of the borer and the flies emerge in February-August. The puparium, 10 mm.×3·8 mm., is described by Gardner, 1940, *tit. cit.*, p. 234, fig. 3.

Nemoraea ornata on *Lymantria incerta* (Lymantriidae). The puparium, 10×5 mm., is described by Gardner 1940, *tit. cit.*, VI, No. 7, p. 238.

Nemoraea tropidobothra is parasitic on Lymantriidae in north India.

Nemorilla floralis is a European species with a large number of hosts. In India it attacks the larva of *Hapalia machaeralis* (Pyralidae). The species is oviparous, the egg being laid on the skin of the caterpillar. The puparium, 5·5 mm., is described.

Pales aurescens on the caterpillar of *Euproctis bipunctapex* (Lymantriidae), passes the cold weather as a dormant larva within the host. The puparial period is 26-40 days in February, March.

Pales pavida on the caterpillars of *Diacrisia obliqua* (Arctiidae), *Malacosoma indica* (Lasiocampidae), *Pyrausta coclesalis* (Pyralidae). The fly emerges from the cocoons of *Diacrisia* in February after a puparial period of 40–60 days, and in August after only 12 days; and in May in the case of *Malacosoma* at high altitudes.

Pales townsendi on *Hyposidra talaca* (Geometridae) or *Phytometra limbirena*. The puparium is described by Gardner, 1940, *Ind. For. Rec.*, VI, No. 7, p. 246, fig. 41.

Phania indica on *Sylepta* sp., (Pyralidae). The puparium, 5 mm. long, is described.

Plagioderophagus niger on the larva of *Plagiodera rufescens* (Chrysomelidae) inside which the puparium, 3·2×1·8 mm., is formed; the fly emerges in April. The puparium is described by Gardner, 1940, *tit cit.*, VI, No. 7, p. 240, fig. 24.

Podomyia setosa. A parasite of *Plecoptera reflexa* (Noctuidae), the shisham defoliator, in north India where it is of considerable importance as a natural check on the increase of the defoliator in shisham plantations. Other hosts are *Argina argus* (Arctiidae), *Pyrausta coclesalis* (Pyralidae), *Lamida carbonifera*, *Prodenia litura* (Noctuidae).

Life-history: The minute, pear-shaped, black egg is laid on the edge of a young leaf, and is taken into the mouth of the caterpillar when it bites off the piece of leaf. It is small enough, 0·2 mm., to be swallowed by third stage and older larvae without damage. A female lays 250–300 eggs which remain viable for up to 3 weeks from the date of deposition, i.e., an egg hatches after being eaten no matter whether it is one day old or 20 days old. The parasitic larva feeds to some extent in the maturing caterpillar which however pupates successfully. The parasite then continues its development in the pupa of the *Plecoptera* and eventually forms its puparium, [fig. 131], 5–13 mm. long, average 7×3·5 mm., within the blackened and distended pupal shell. Only one fly develops in each parasitised caterpillar. If several eggs are swallowed the surplus parasites fail to reach maturity and both host and parasite die. Superparasitism to the extent of

15 *Podomyia* larvae has been obtained artificially. The tachinid fly emerges about a week later than the moth would have emerged. The total life-cycle from ingestion of the egg to emergence of the fly is about 11–18 days in the quickest season, April–August (larval period 6–9 days, pupal period 5–10 days). From September the life-cycle lengthens considerably; the puparial period is 8–14 days in September, 14–30 days in October–November, 27–40 days in November–December. In the colder districts *P. setosa* hibernates for 3 or 4 months as a puparium or immature fly within the pupa of the host. The flies of the late broods of the year also remain alive for a few weeks.

Podomyia setosa may have a sequence of ten generations in the year, lasting about 18 days (2+8+8) in the hot months and 40 to 45 days in the autumn. It is therefore adjusted to the sequence of generations of the host which are also ten in north India. The percentage-parasitism of larvae of *Plecoptera reflexa* in shisham plantations is variable and often low but may rise to over 50.

Frontina kashmiri Tothill, 1918, and *Prosopoea indica* Curran, 1933, are synonyms.

Beeson and Chatterjee S. N., 1935, *tit. cit.*, I, No. 9 p. 178.
Gardner J. C. M., 1940, *tit. cit.*, VI, No. 7, p. 236, fig. 10, (puparium).

Prosena sybarita on the larvae of *Adoretus* and Cetoniinae (Scarabaeidae).

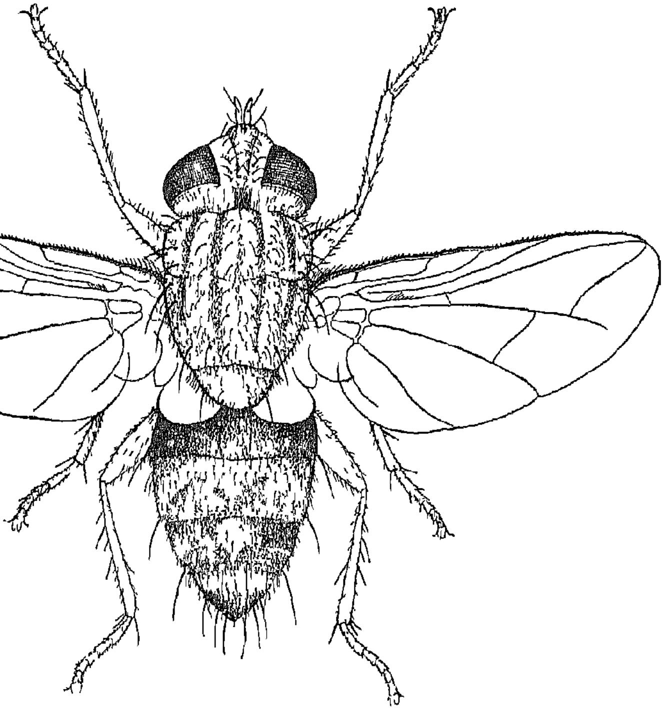
Prosopodopsis fasciatus on the caterpillar of *Pyrausta coclesalis* (Pyralidae), one larva maturing in each host and emerging after the formation of the pupa by *coclesalis* to make its puparium either within or alongside the pupal skin. The puparium, 6×2 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 237, fig. 13. The fly appears in July–October.

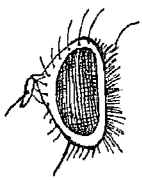
Ptychomyia remota

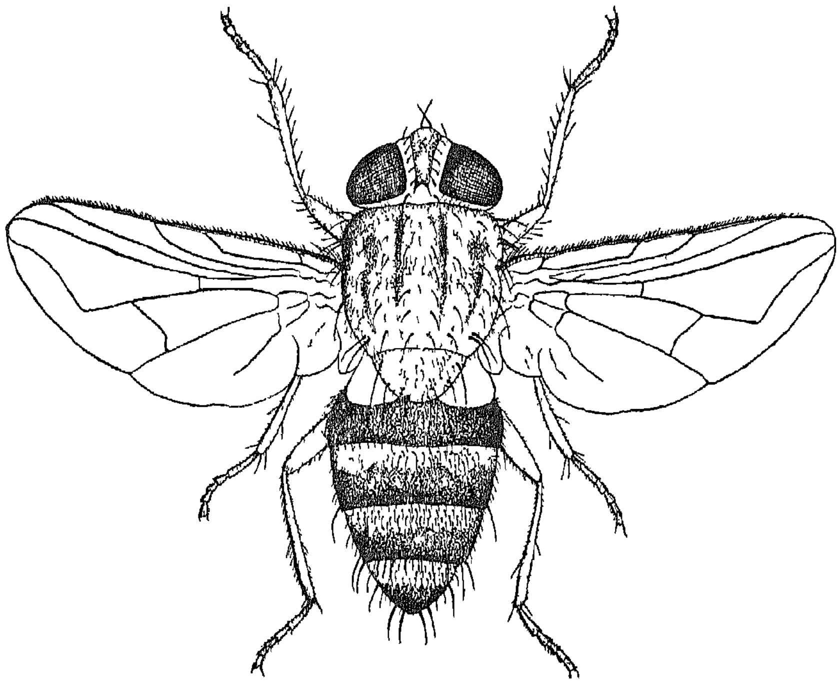
The hosts are *Achaea janata* (Noctuidae), *Artona catoxantha* (Zygaenidae), *Hapalia machaeralis* (Pyralidae), *Hyblaea puera* (Hyblaeidae), *Levuana iridescens* (Zygaenidae) and *Sylepta derogata* (Pyralidae). It is widely distributed in the Oriental Region.

Life-history: This species was first recorded as a parasite of *Artona catoxantha*, a pest of coconut palms in the Federated Malay states and was introduced into Fiji in 1925 to control *Levuana iridescens* also a defoliator of coconut palms which was threatening the industry in the Fiji Islands. All stages are figured and described by Tothill, Taylor and Paine, 1930, *The Coconut Moth in Fiji*. The egg is usually laid on the intersegmental skin of the thorax and first abdominal segments; the incubation period is about 40 hours; the larval period is variable between wide

Fig. 132. Above, Eutachina fallax, 8-10 mm.
Below, Sturmia inconspicuella, 6-9 mm.







limits, viz., 4 to 15 days, depending on the stage of the host at the time of oviposition; the pupal period has a normal range of 8 to 11 days. The adult lives for at least 10 days. One parasite normally matures in each host although superparasitism frequently occurs. The puparium is formed externally after the host has spun its cocoon. In Malaya the life-cycle is about 20 days (Gater). In India it attacks both species of teak defoliators but is apparently not a regular parasite of them. Puparia were imported from Burma in 1938 and flies were released in Nilambur, Madras.

Beeson and Chatterjee S.N., 1935, *tit. cit.*, I, No. 8, pp. 178, 179 (references).
Gater, 1925, *Malayan Agric. Journ.*, XIII, pp. 92-115.
— 1926, *tit. cit.*, XIV pp. 321-339 (life-history in Malaya).
Gardner J. C. M., 1940, *Ind. For. Rec.*, VI, No. 7, p. 245, fig. 40 (puparium).

Raphis elongata on the caterpillar of *Phassus malabaricus* (Hepialidae); the fly emerges in May during the flight-period of the host. The puparium, 11 × 2 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 239, fig. 19.

Sturmia atropivora on the caterpillars of *Acherontia* and other Sphingidae and of *Caprinia conchylalis*, *Margaronia laticostalis* (Pyralidae). It is widely distributed in the Oriental, Ethiopian and Palaearctic Regions. The life-cycle varies in conformity with that of the host being very long in sphingid caterpillars; emergence for the formation of the puparium takes place after the host has entered the soil. In the larger host-caterpillars numerous parasites reach maturity. The puparium, 5 × 2 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 238, fig. 15.

Sturmia bella is a widely distributed species parasitic on the caterpillars of butterflies of the genera *Argynnis*, *Pyrameis* and *Vanessa*, also on Lasiocampidae, Lymantriidae and *Acontia intersepta* (Noctuidae). In India it has been reared from *Danais chrysippus*, *Papilio demoleus* and *Vanessa kashmirensis*. Several parasites reach maturity in one caterpillar. The puparial period is 7 to 10 days, average 8, in May. The puparium, 8 × 4 mm., is described by Gardner, 1940, *tit. cit.*, VI, No 7, p. 241, fig. 26.

Sturmia chatterjeeana parasitises the caterpillars of *Euproctis bipunctapex* (Lymantriidae). The puparial period is 11-18 days in March, April. The puparium, 8 mm. long, is described in Gardner, 1940, *tit. cit.*, VI, No. 7, p. 246.

Sturmia chatterjeei is a parasite of the caterpillar of the Deaths Head Moth, *Acherontia lachesis* (Sphingidae). Over 50 flies may develop in one caterpillar. The maggots leave the body of the host when full fed and pupate in the soil. The puparial period is 9 days in June.

Sturmia inconspicua

A European species occurring also in the north west Himalayas. It was introduced into the United States of America, first in 1906 and finally colonised in 1927, to assist in the control of

the Gypsy Moth and also into U. S. A. and Canada to control the Spruce Sawfly.

Life-history: In India its hosts are *Lymantria obfuscata* (Lymantriidae) and *Malacosoma indica* (Lasiocampidae). The female oviposits by extending the ovipositor between the legs and attaching an egg to the skin of the host. The larva hatches immediately and disappears within the body of the host in 5 to 10 minutes. The average duration (in the U. S. A.) of the larval period is 14 days and of the puparial period 10 days; the puparium is rarely formed within the host, more usually within the cocoon or nearby or in the soil. In the Himalayas the flies emerge in April–June and there must evidently be alternative hosts during the monsoon season and autumn.

Beeson and Chatterjee S. N., 1935. *Ind. For. Rec.*, Ent., 1, No. 9, pp. 180, 181.

Sturmia inconspicuella

An internal parasite of the caterpillars of *Diacrisia obliqua* (Arctiidae), *Hyblaea puera* (Hyblaeidae), *Euproctis fraterna* (Lymantriidae), *Hapalia machaeralis*, *Jocara malefica*, *Lamida carbonifera*, *Margaronia laticostalis*, *Sylepta balteata* (Pyralidae), *Rhyacia ypsilon*, *Spodoptera mauritia*, *Striglina scitaria* (Noctuidae), *Catopsilia crocale* (Pieridae), *Cerura litura* (Notodontidae).

Life-history: The ovipositor of the female is capable of considerable extension which enables the fly to oviposit without approaching very closely to the caterpillar [fig. 132]. The egg is deposited swiftly and adheres to the skin of the caterpillar, usually the 5th instar. The maggot is almost ready to hatch when the egg is laid and emerges in a few hours to a whole day and bores straight into the body. Up to 5 eggs may be laid on one host and develop successfully to the imaginal stage, but normally only one individual is produced. In north India the life-cycle of the parasite in *H. puera* is 22 to 28 days in October–November (larval period 7–8 days, puparial period of 14–20 days). In central India the puparial stage lasts 8 to 9 days in August–October. In south India the puparial stage lasts 7 days in May and 8–10 days in June to December, which periods are slightly longer than the corresponding pupal periods of the moth. In Burma the life-cycle averages 18 days, about 15 days in summer and 21 days in winter which is about $1\frac{1}{2}$ times as fast as the development of the host. There is however a pre-oviposition period of about 6 days.

The full grown *Sturmia* larva may pupate in the folded leaf prepared by the *puera* caterpillar or in the soil. When *machaeralis* is the host the puparium is usually formed half in and half outside the host's pupal skin. The puparium [fig. 133] is described by Gardner, 1940, p. 235, fig. 6. The flies live up to 7 weeks, the average longevity being about one week. A female

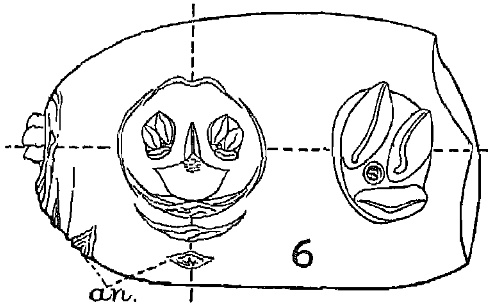


Fig. 133. Puparium of Sturmia inconspicuella, 8×4 mm.; the posterior spiracles and anus are shown in relation to the long and vertical axes (dotted); one spiracular plate is shown enlarged on right.

may lay over 50 eggs,

This species is a regular parasite of *H. puera* and is often responsible for 50 to 100 percent of the total larval parasitism; the monthly parasitism-percentage of the larval population by this species may rise to 60. It travels satisfactorily when despatched by post or ship as puparia packed in sawdust.

Beeson and Chatterjee S. N., 1935, *tit. cit.*, I, No. 9, pp. 181, 182, fig. 2.
Gardner J C. M., 1940, *tit cit.*, VI, No. 7, p. 235, fig. 6, (puparium).
Garthwaite P. F. and Desai M. H., 1939, *tit. cit*, V, No. 4, pp. 345, 346, On the biology of the parasites of teak defoliators.
Beeson and Chatterjee S. N., 1939, *tit. cit.*, V, No. 5. pp. 362, 363.

Sturmia inconspicuoides. The hosts are *Hyblaea puera* (Hyblaeidae), *Crocidolomia binotalis*, *Hypsipyla robusta* (Pyralidae), *Badamia exclamationis* (Hesperiidae), *Fodina stola*, *Laphygma exigua*, *Plusia orichalcea* (Noctuidae), *Danais chrysippus*, *Vanessa kashmirensis* (Nymphalidae); also Arctiidae, Geometridae and Sphingidae. It is a widely distributed species extending from south India to Australia, and is only a casual parasite of the teak defoliator. In one larva of *P. orichalcea* 3 parasites may mature; the fullgrown larva is 10 mm. long; the puparium is 8×4 mm.

Garthwaite P. F. and Desai M. H., 1939, *tit. cit.*, V, No, 4. p. 346.
Gardner, 1940, *tit. cit.*, VI, No. 7, p. 235, (puparium).

Sturmia macrophallus on *Semiothisa fidoniata* (Geometridae). The puparium, 4·5 mm., is described by Gardner, 1940 *tit. cit.*, p. 234, fig. 2.

Sturmia nigribarbis on the larva of *Hapalia machaeralis*, emerging from the prepupal larva and pupa in order to form the puparium, 5×2 mm, which is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 238, fig. 17. Occurs from South India to Burma but is uncommon.

Sturmia parachrysops on the larva of *Hapalia machaeralis* forming its puparium in the web of the host. It also parasitises

Psara bipunctalis (Pyralidae). Occurs from south India to Malaya but is a rare parasite of *H. machaeralis.* The puparium, 6 mm. × 3 mm., is described by Gardner, 1940, *tit. cit.*, p. 235, fig. 5.

Sturmia sericariae on the Mulberry Silkworm, *Bombyx mori* (Bombycidae) and numerous large caterpillars, Arctiidae, *Eupterote undata* (Eupterotidae), *Trabala vischnou* (Lasiocampidae), *Papilio demoleus* (Papilionidae), *Cephnodes hylas* (Sphingidae), etc. It occurs throughout the Oriental Region. The puparium is described by Gardner 1940, *tit. cit.*, VI, No. 7, p. 241, fig. 27a, 27b.

Sturmia vicinella on *Theretra oldenlandiae* (Sphingidae). The puparium, 9 mm. × 4 mm., is described by Gardner, 1940, *tit. cit.*, p. 235.

Sturmia zebina is a widespread oriental species that occasionally parasitises *Hyblaea puera*, emerging from the pupa.

Thelaira nigripes parasitises *Amsacta lactinea*; the puparial period is 7 days in August; the puparium, 7 mm., is described.

Thrycolyga impexa has been bred from larvae of Syrphidae predaceous on small caterpillars including Arctiidae boring the pods of *Crotolaria sericea* and *Sutherlandia* and from caterpillars of *Tarucus venosus* (Lycaenidae) defoliating *Prosopis spicigera.* The puparial period of *T. impexa* is 8 weeks in December-February. The puparium, 5 mm., is described Gardner, 1940, *tit. cit.*, p. 234, fig. 1.

Thrycolyga sorbillans occurs throughout the Oriental Region and in the Ethiopian and Palaearctic Regions and has been introduced to North America. It is parasitic on numerous families of Lepidoptera; its hosts in India are *Acherontia lachesis* (Sphingidae), *Cricula trifenestrata*, *Philosamia cynthia ricini* (Saturniidae), *Andraca bipunctata*, *Bombyx mori* (Bombycidae), *Dasychira mendosa*, *D. thwaitesi*, *Thiacidas postica*, *Lymantria semicincta*, *Perina nuda* (Lymantriidae), *Cavira ochripes*, *Metanastria hyrtaca* (Lasiocampidae), *Hyposidra talaca* (Geometridae), *Iugura subapicalis* (Noctuidae).

As many as 25 parasites may reach maturity in a large caterpillar. The puparial period is 8–12 days in May, 7–10 days in the hot weather, 26 days at the end of September and about 55 days in the cold months November-January. The puparium, 7 × 3·5 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 244, fig. 37.

Voria edentata on *Pieris brassicae* (Pieridae) in north India. The puparium, 6 mm., is described by Gardner, 1940 *tit. cit.*, p. 236, fig. 9.

Winthemia albiceps a widely distributed species, India to Australia, on *Achaea janata* (Noctuidae), *Catopsilia crocale* (Pieridae), *Hyblaea puera* (Hyblaeidae) and Sphingidae. **Winthemia dispar** which has also been bred from *H. puera* may be indentical with *W. albiceps.*

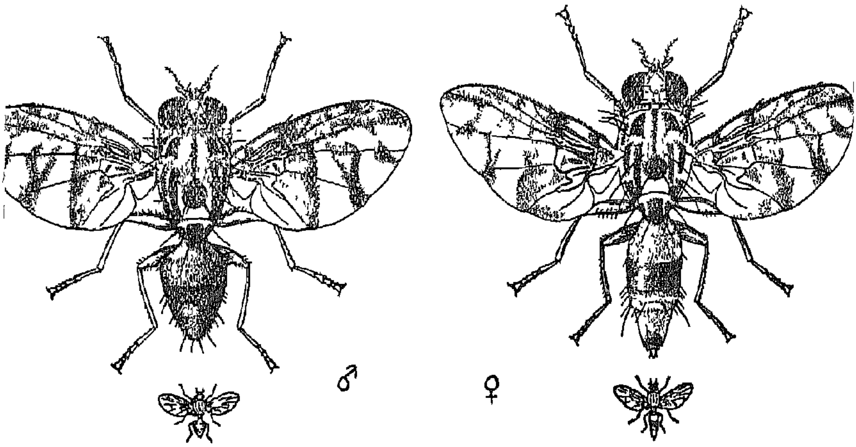


Fig. 134. Chelyophora ceratitina, male and female flies, 8 mm.

Winthemia diversa is parasitic on *Prodenia litura* (Noctuidae). The puparium, 8·5 mm., is described.

Winthemia quadripustulata, a widely distributed palaearctic species, has been recorded from *Diacrisia obliqua* (Arctiidae). See Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 9, p. 184.

Winthemia trichopareia on *Metanastria hyrtaca* (Lasiocampidae). The puparium, 10×4·5 mm., is described by Gardner, 1940, *tit. cit.*, VI, No. 7, p. 243, fig. 33.

Zenillia roseanellae is a fairly regular parasite of *Hapalia machaeralis* (Pyralidae) in Burma; also on *Dichocrocis* sp. boring the fruit of *Randia uliginosa*. The full fed maggot emerges from the prepupal larva; the puparial period is 9 days in June–August; the puparium, 6 mm., is described in *Ind. Journ. Ent.*, 1941.

TIPULIDAE

LARVAE of this family, known as 'Leather-jackets', are injurious in temperate regions to the roots of agricultural crops, seedlings of trees, pasture land, grasses, etc. Nothing similar has been recorded in the Indian region, but the TIPULIDAE (or Craneflies) have been neither collected or investigated specially.

TRYPETIDAE

FRUITFLIES form a small family of about 1,000 species of which nearly 150 occur in the Indian region. The flies have clouded or patterned wings [fig. 134] and bright colouration. The larvae are white, yellowish or pinkish maggots, some of which are able to jump. Larval food comprises (a) fruits of trees, lianes and

creepers from small berries to large gourds or melons, which are oviposited when quite healthy and attached to the plant, or when over-ripe, fermenting or rotting, according to the specific habit; (b) flower-heads, particularly of Compositae and Umbelliferae without making galls; (c) in various parts of a plant causing the formation of galls; (d) growing shoots of bamboos.

LITERATURE ON TRYPETIDAE:

Much has been published in other countries on the biology and economics of the Cherry Fly, the Mediterranean Fruit Fly, the Melon Fly, the Olive Fly, etc.

Bezzi M., 1913, *Mem. Ind. Mus.*, III, pp. 53-175, pls. viii-x, Indian Trypaneids (Fruit flies).

Munro H. K., 1934, *Rec Ind. Mus.*, XXX, pp. 15, Records of Indian Trypetidae with descriptions of some new species.

Senior White R., 1924, *Catalogue Ind. Ins.*, Part 4, Trypetidae.

Carpomyia vesuviana, a Mediterranean species, breeds in fruits of *Zizyphus jujuba* and *Z. sativa*.

Chaetellipsis paradoxa breeds in damaged shoots of *Bambusa burmanica* and other bamboos in India. The larvae tunnel on the outside of the node between the epidermis and the culm-sheath during the early part of the growing-period in the monsoon. The male fly, 6 mm. long, differs considerably from the female, 7 mm. with ovipositor, which was described as *Poecillis judicanda* and represents the most remarkable case of sexual dimorphism known in the family.

Chaetodacus correctus breeds in fruits of *Aegle marmelos*, *Mangifera indica* and *Prunus persica*. **C. cucurbitae**, the Melon Fly, breeds in pumpkins, melons, cucumbers, wild gourds, etc. and also under the rotten bark of *Ficus nemoralis* and *Ilex hookeri*. There is an extensive literature on this pest. U. S. Department of Agriculture Bulletins give complete bibliography.

C. ferrugineus in fruits of *Artocarpus integrifolia*, *Calotropis procera*, *Citrus* spp., *Mangifera indica*, *Prunus persica*, *Psidium guava*, and *Putranjiva roxburghii*. **C. zonatus**, the Peach Fruitfly, in fruits of *Aegle marmelos*, *Mangifera indica*, *Prunus persica* and spp., *Pyrus* spp., *Citrus* spp. and also certain vegetables.

Chelyophora ceratitina breeds in shoots of *Dendrocalamus strictus*. Fig. 134 shows the male and female flies, 8 mm., yellow with black spots on the thorax and scutellum, wings yellow-banded. The pinkish-grey larvae completely eat out the soft tissues of the young shoot leaving only the culm-sheaths. The attack of this fly is probably secondary to that of *Argyroploce paragramma*. Broods mature in October–December. **C. striata** similarly destroys the shoots of *Dendrocalamus giganteus* in south India and Ceylon.

Leptoxyda longistyla breeds in the fruits of *Calotropis gigantea* and *C. procera*.

Rhacochlaena cassiae breeds in the pods of *Cassia fistula*.

EPHEMEROPTERA

THIS Order, which comprises less than 1000 species of Mayflies, is of no direct importance to forestry. The aquatic nymphs and their ephemeral winged adults are a staple food of fishes; and 2 or 3 species have been recorded as wood-borers. Nymphs of **Anagenesia** are considered to be responsible for serious damage to the woodwork of boats kept on lakes or jhils. **Povilla corporaali** (according to the observations of R. N. De, Assam Forest Service), in the last nymphal instar bores into the trunks of partially submerged living trees and excavates closely crowded chambers that groove the inner bark and sapwood; in *Crataeva religiosa* the chamber is lenticular, about $1 \times \frac{3}{16}$ or $\frac{1}{4}$ inch and $\frac{1}{8}$ to $\frac{1}{4}$ inch deep in the sapwood and is possibly used for the last ecdysis. The genus is placed in a group of the POLYMITARCIDAE in which the nymph lives on the bottom of ponds or jhils and is a burrower with forelegs modified like scrapers and the mandibles produced into long tusks. The adult mayflies swarm in "millions"; the eggs are deposited in large numbers in gelatinous strings.

Chopra B. N., 1927, *Rec. Ind. Mus.*, XXIX, pp. 91-138, pls. viii-x, The Indian Ephemeroptera.

Hafiz H. A., 1937, *lit. cit.*, XXIV, pp. 351-370, Indian Ephemeroptera of the suborder Ephemeroidea.

HYMENOPTERA

THE ORDER HYMENOPTERA

MANY authorities who attach more importance to instinctive behaviour and social organisation than to morphological perfection place the Order HYMENOPTERA at the head of the linear arrangement of insect orders—and, as a corollary, the honeybees at the head of the insect world. Some of the higher ants, bees and wasps, it is held, have developed instinctive behaviour to its highest state of efficiency and are, moreover, intelligent enough to learn by experience. Other authorities, giving greater weight to the specialisation of mouth-parts and wings, consider the Diptera and Siphonaptera to be the most highly evolved insects.

According to a recent estimate the Order has over 86,000 named species in the world and is the third largest. In the Indian Region the ants, fossorial wasps and solitary bees were the first to receive attention from systematists; in modern times more progress has been made with the parasitic Hymenoptera. There are very few monographs and catalogues (see references).

Ecology: There is a remarkable variety of adult and larval habits which makes a complete ecological synopsis of the Order a rather complex structure. Adults are concerned with more than feeding and copulation; many types show elaborate parental foresight and care for the brood, employing diverse methods of collecting and storing food for the larva; social habits grade from loosely associated colonies to the organised states of

ants and honeybees. Among the larval habits exist all grades of parasitism, i.e., parasitoids internal and external of egg, larva, pupa and adult of the host, hyperparasites, non-fatal parasites, parasitoids on paralysed hosts, predator-robbers, social parasites, inquilines; in the more specialised modes of life the varieties of larval morphology and metamorphosis are manifold. Polyembryony and alternation of generations are other features. From this variety of types a few characteristic examples have been selected for the following simplified synopsis:

Synopsis of larval habits.

(1) NON-SOCIAL INSECTS.

(a) **Phytophagous larvae—**
Sawflies, e g., Tenthredinidae
Gallwasps, e.g., Cynipidae
Woodwasps, e.g., Siricidae, Xiphydriidae

(b) **Carnivorous larvae or Parasites—**
Internally in active host, e g., Bethyloidea, Chalcidoidea, Ichneumonoidea, Serphoidea
Externally on active host, e.g., some Braconidae, some Eulophidae, Scolioidea
Externally on paralysed host, e.g. some Braconidae, Sphecoidea, Eumenidae
Hyperparasites, e.g., some Chalcidoidea, Chrysididae, some Ichneumonidae

(c) **Larvae in cells made by adult—**
Cell of mud, (fossorial wasps), e.g., Eumenidae, Sphecoidea
Cell of leaves, (leaf-cutting bees), e.g., Megachilidae
Cell of wood, (carpenter bees), e.g., Xylocopidae

(2) SOCIAL INSECTS.

(d) **Larvae in cells made by adult—**
Cell of carton pulp, (wasps and hornets), e.g., Vespoidea
Cell of wax, (bees), e.g., Apidae, Bombidae

(e) **Larvae in ants' nest not in cell,** Formicidae

Economic importance: "This Order must be reckoned the most highly beneficial of all Orders of Insects. The unceasing work of thousands of parasitic Hymenoptera is the principal factor in the maintenance of the balance of insect-life, whereby hosts of injurious species of beetles, flies and moths are prevented from overrunning the world. The study of the life-histories of such forms, and the utilisation of their aid in checking introduced pests, is one of the chief hopes of the future for economic biology. Ants, too, on the whole are highly beneficial in removing and destroying animal and vegetable debris, though some undoubtedly offset this by the fostering care which they lavish on aphids and scale-insects. The Honey Bees supply mankind with the one universally valued insect-food, *honey*; while bees and flower-wasps are responsible for the fertilization of certain fruit-trees and fodder-crops as well as of many garden flowers." (Tillyard).

Synopsis of the families of the Order HYMENOPTERA

Suborder CHALASTOGASTRA

TENTHREDINOIDEA	**Tenthredinidae**
SIRICOIDEA	**Xiphydriidae**
	Siricidae

Suborder CLISTOGASTRA

Division TEREBRANTIA

ICHNEUMONOIDEA	**Evaniidae**
	Ichneumonidae
	Braconidae
CHALCIDOIDEA	**Torymidae**
	Chalcididae
	Eurytomidae
	Perilampidae
	Miscogasteridae
	Encyrtidae
	Pteromalidae
	Elasmidae
	Eulophidae
	Trichogrammatidae
SERPHOIDEA	**Serphidae**
	Scelionidae
	Calliceratidae
CYNIPOIDEA	**Cynipidae**

Division ACULEATA

BETHYLOIDEA	**Bethylidae**
CHRYSIDOIDEA	**Chrysididae**
SCOLIOIDEA	**Scoliidae**
	Mutillidae
FORMICOIDEA	**Formicidae**
VESPOIDEA	**Vespidae**
	Eumenidae
SPHECOIDEA	**Sphecidae**
	Crabronidae
APOIDEA	**Megachilidae**
	Xylocopidae
	Apidae

NOTE: The above synopsis on the whole follows the nomenclature and serial order adopted by Brues and Melander, 1932. The names of numerous families have been omitted but all the names discussed in this book are included.

LITERATURE ON HYMENOPTERA :
For biologies and systematics of families see under families.

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— 1925, *Catalogue Ind. Ins.*—Part 10, Stephanidae.

Fletcher T. B., 1926, *Agr. Res. Inst.*, Pusa, Bull. 162, pp. 55-73, pl. IX, Tentative keys to the orders and families of Indian insects.

Mani M. S., 1937, *Catalogue Ind. Ins.*, Part 23, Chalcidoidea,—1939, *tit. cit.*, Part 24, Evaniidae.

Morley C., 1913, *Fauna Brit. Ind.*, Hymenoptera III, Ichneumonidae I, 531 pp., figs, pl.

APIDAE

HONEY BEES are represented by 3 species of the genus **Apis** which are indigenous and a fourth which has been imported.

Castes of Bees: A colony of honey bees contains 3 castes, Queen, Workers, and Drones.

The *Queen bee* is a female which has mated with a male or Drone and is the only fertile female living in a colony of bees. She is about 1½ times as large as a worker bee, with relatively short wings and elongated pointed abdomen; the reproductive organs are fully developed; the pollen-collecting and wax-secreting structures are absent. She lays on an average several hundred eggs daily and at the most prolific season may lay 1,500 to 2,000 eggs in one day and if she lives for 3 to 5 years may produce a total of 1½ million eggs. Eggs are either fertile, which produce worker bees, or unfertilised, which hatch into drones. The egg which produces a queen is a normal worker bee egg, but the larva hatching from it is reared on a special food (royal jelly) secreted by certain glands in young worker bees (nurse bees); as the larva grows in size its cell is specially lengthened and shaped and sealed differently to the normal brood cells. A queen can be produced in 15 days from the laying of the egg.

The *Worker bee* is the mainspring of the colony and is responsible for all the work. In appearance it is similar to the queen but shorter and with the reproductive organs undeveloped. The sting is an additional organ of 2 barbed lancets in a dorsal sheath connected with a bulb and 2 poison glands, one secreting an acid and the other an alkali. When the sting is used the lancets and the sheath are thrust into the object and the bee is unable to withdraw them thereafter because of the barbs. The

sting and the muscles and the poison sac are torn from the body of the bee which usually succumbs to the injury. Worker bees visit flowers in order to collect food (nectar and pollen) and in the process they pollinate the flowers and are particularly important agents of cross-pollination. Nectar is swallowed and taken to the hive where it is stored in cells in the comb and becomes honey; pollen is used for feeding the larvae. It is collected by the worker in its mouth and moistened and then transferred by means of the legs and packed into the pollen-basket (corbicula) a small groove on the outer surface of the hind tibia (one on each hind leg). The lumps of pollen are conspicuous on the hind legs of bees returning to the hive. Water is also collected and resin or gum from plants is used for repairs to the hive.

Wax: Worker bees secrete wax from glands in the abdomen; the secretion is exuded between the segments of the underside of the abdomen and hardens to form scales of wax. A wax-scale is detached from the abdomen by the spiny brushes on the inner surface of the flat expanded tarsal segment of the hind legs and is passed forward to the mouth in which it is chewed and made plastic for the building of the comb-cells. The comb is constructed of thin-walled, hexagonal cells in two opposite layers on a common base so arranged that each side wall serves for two adjacent cells and each cell-base serves for two opposite cells; the base is composed of 3 parallelograms. The plane of the comb is vertical and the cells lie horizontally.

The larva of the worker bee, which hatches from an egg placed in a brood-cell by the queen, is fed liberally at first by a secretion of the nurse bees but latter the diet is changed to coarser food, a mixture of honey and pollen (bee bread). In about 5 days it is full grown and the cell is sealed. The larva spins a thin silken imperfect cocoon, pupates and the adult emerges after a life-cycle of about 3 weeks. The young worker bee remains in the hive for 2 or 3 weeks performing the duties of nurse bee, in attendance on the queen or brood-cells or building the wax-cells. Later the worker bee takes on field-work and is constantly occupied in the collection of nectar and pollen. Other duties undertaken by sections of the worker population are guarding the hive or comb, air-conditioning, temperature-regulation, and ripening of nectar in the manufacture of honey.

The *Drone bee* is the male, a broad blunt-bodied bee with a rounder head and large eyes; it has no sting or wax-producing structures but the reproductive organs are fully functional. It is reared in a large cell, from an unfertilised egg. The adult drone is unable to feed himself and is dependent on the workers for food. The sole function of this caste is to ensure the fertilisation of a virgin female when she leaves the colony on a nuptial flight. Drones follow in a swarm and the individual that mates with the queen dies immediately after copulation; the generative organs are

ejaculated and torn off. After the swarming-season is over surplus drones are driven from the hive by the workers.

Swarming: The swarming of bees originates because of lack of room, lack of food or the unsafe condition of the old nest and not, as has been thought, owing to the nuptial flight. It is a division of the bee stock in which the sexual impulse has no part *and arises from an instinct impelling migration towards favour*able conditions of food and colonisation. It is not due to physiological reflexes and to particular stimuli because it is too harmonious a proceedure for a state composed of many castes.

Honey: Nectar collected by worker bees from flowers is ingested into the honey-stomach. On return to the hive the collector bees regurgitate the nectar and pass it to others who put it through a process of partial digestion in which the cane sugar of nectar is split into simpler sugars (glucose and levulose). The partially digested fluid is stored in cells in the comb and evaporated or ripened by fanning currents of air over the open cells; when the cells are completely filled with ripened viscid honey they are capped and stored as food for the colony through the winter season. Thousands of trips covering thousands of miles have to be made by the bees to collect enough nectar for one pound of honey. Honey varies in colour from white to almost black depending on its composition as determined by the flowers from which the nectar is collected; it also varies in flavour. In its marketable form honey is procurable in the comb, strained, extracted or granulated. Honey collected from the combs of wild bees is usually obtained by crushing the combs and straining through a cloth. Most honeys become cloudy or granulated after storage owing to the crystallisation of the sugars.

Beeswax: Beeswax is usually isolated or rendered from combs by heating in a cloth bag in a vessel of boiling water. The bag is held under water and pressed with a stick from time to time to force out the molten wax which melts at a temperature of 145° F. As the wax rises to the surface of the water it is removed by means of a large spoon and cooled and solidified in cold water. This method is very wasteful and loses about a quarter of the wax and also yields an impure product.

Apis dorsata, the Rock Bee is the largest of the indigenous species of *Apis*, its worker (20 mm.) being about as big as the queen of the European honeybee, *A. mellifica*. A swarm builds a single large comb usually about 3 feet wide but as much as 5 feet long; the comb is fully exposed, suspended on the face of precipitous rocks, cliffs, river-gorges, etc. or to the larger branches of tall trees or occasionally on the walls and eaves of high buildings. Frequently many nests occur together in a favorable place and the building sites of a colony are used year after year. This Large Bee is found in dry forests and in wet regions and in the

mangrove forests of the Sunderbans and in the mountains. *A. dorsata* migrates twice a year—from the plains to the hills in the monsoon and returns to the plains about mid-winter. (Swarms of this bee regularly settle and halt for a time under the eaves of the upper storey of the Forest Research Institute.) Migration in some seasons appears to be connected with the periodic gregarious flowering of *Strobilanthes*. The flower secretes honey in a small disc below the ovary and is very attractive to *A. dorsata* and *A. indica*. The workers build a new nest and this is followed by the swarming of the queen.

Honey and wax of this species form a minor forest product. A single comb may yield as much as 60 pounds of honey. Two crops a year are produced by a colony usually maturing at the begining and the end of the rains. The beeswax exported from India, valued at several lakhs of rupees annually, is derived mainly from this species Collection is carried on after a crude fashion by the men of jungle tribes, who climb bee-trees or are lowered by ropes over cliffs, usually at night. The only protection adopted is a blanket and a torch; the bees are burnt or smoked off the comb which is then cut away bodily. *A. dorsata* is a particularly fierce and irritable bee, readily attacking those who disturb its nest or approach a colony, and frequently pursuing an intruder for miles. Men and animals (including the elephant), have been stung to death by Rock Bees. Accounts of fatal injuries are not infrequent in the daily newspapers. It is obviously not a species suitable for domestication, but it is an important factor in pollination. A worker may visit 20 to 30 flowers a minute and its daily work has been estimated at 12,000 pollinations.

Apis florea, the Little Bee. The worker of this species is exceptionally small compared with its drone and queen, which are smaller than those of the Indian Bee. *A. florea* is non-gregarious and builds a single comb, usually not more than 6 inches across, placed inside bushes supported by small forking branches, or suspended from a large branch or under the eaves of buildings. This bee does not produce much honey, a single comb yielding a a few ounces only. It is not very irritable and rarely stings; the sting causes a slight swelling but is by no means so painful as that of the bigger bees. The nests in consequence are commonly robbed when found.

Apis indica, the Indian Bee. Its nests occur singly, in sheltered places such as cavities in trees, within thick bushes, between rocks, and often inside the walls or roofs of houses, even in disused boxes and cupboards. Several parallel combs about a foot across side by side constitute one nest. The Indian Bee is not so productive in honey as the Rock Bee. The yield of honey from one nest may reach 6 or 7 pounds annually. It is however, extensively collected as a minor forest product.

The species readily swarms and migrates to some extent but

it shows distinct varieties in the hills and in the plains. The hills variety is slightly larger and darker in colour and less irritable and less vagrant and more productive than the plains variety. *A. indica* is the only indigenous species capable of domestication and establishment in artificial hives. "It is common, easily obtainable almost everywhere and easily kept in frame-hives, except that it often shows a tendency to desert the hive after a few months; a drawback is its small yield of honey, which only averages about five or six pounds per hive yearly. In orchards and similar places, where bees are required to pollinate flowers it should, however, be well worth while to keep these bees for this end alone". (Fletcher).

Apis mellifica. The hive bee or honey bee of Europe, *Apis mellifica*, has been domesticated and improved by breeding for many centuries and numerous varieties now exist, the most useful being Italian varieties. On account of its superior qualities the Italian bee has been introduced into practically all countries where beekeeping is carried on on modern lines.

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BETHYLIDAE

LITERATURE ON BETHYLIDAE:

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Goniozus montanus is ectoparasitic on the larvae of *Agrotera basinotata*, *Chalcidoptera straminalis*, *Lygropia quaternalis*, *Sylepta crotonalis*, *S. balteata* (Pyralidae), *Hyblaea puera* (Hyblaeidae), *Striglina scitaria* (Noctuidae), *Cacoecia* sp. (Tortricidae). From 3 to 9 adults mature on one host. The eggs are laid on the skin of the paralysed caterpillar and the female remains on guard over the brood until they are full grown, a matter of only a few days. The cocoons are formed of loose, dark brown silk, more or less spindle-shaped and closely congregated in a cluster; the cocoon-period lasts 7 days. The total life-cycle lasts about 11 days (1+3+7). This species was sent by air mail to Burma from Nilambur in 1938, and to North Thana, Bombay, in 1939.

Perisierola nephantidis, 3 mm., is a parasite of *Nephantis serinopa* (Xyloryctidae).

Trissomalus fulvicornis is parasitic on the caterpillar of *Argyroploce illepida* (Eucosmidae).

BRACONIDAE

SOME hundreds of species of Indian BRACONIDAE have been named by Ayyar, Cameron, Nixon and Wilkinson; the unnamed species are still very numerous. The legless maggot-like larvae occur in forms similar to those of the Ichneumonidae but are distinguished by features of the tracheal system; endophagous types have a globular tail or caudal vesicle. Adults are separable from those of other Ichneumonoidea by the wing-venation.

The hosts are chiefly larvae of Lepidoptera and also some groups of Diptera, Rhynchota and bark-boring and wood-boring Coleoptera are parasitised; some Braconidae are hyperparasites. Most species of hosts support only one parasite in each parasitised individual; in relatively few cases as many as a thousand adult parasites can mature in one large caterpillar of Sphingidae or Saturniidae. A single female can lay scores of eggs and, under laboratory conditions, may be induced to parasitise hundreds of individuals which is usually many more than is customary under natural conditions. Parthenogenetic reproduction takes place under certain conditions, the progeny of the unfertilised female being usually males. The egg is laid (a) on the host and the larvae feeds externally as an ectoparasite throughout its short life, e.g., *Cedria*, *Microbracon*, or (b) inside the host and the larva is endophagous, pupating inside the body or cocoon of the dead host, e.g., *Cremnops* [fig. 136], or emerges to spin a cocoon outside, e.g., *Apanteles*, *Meteorus* [fig. 137], *Microgaster*. The cocoons may be formed (i) singly in the case of solitary species, e.g., *Phanerotoma*, or (ii) gregariously in a cluster, e.g., *Apanteles*, *Exobracon*, or (iii) communally in the form of a tent-like covering, e.g., *Cedria* [fig. 135]. The number of generations of a parasite conforms to that of its host and varies from one to 19 per annum; a species dependent on more than one species of host is usually adaptable to variations in the abundance and sequence of its hosts.

Biological control: Many of the species of this family are useful agents in the natural control of pests of forestry. Estimates of the fluctuations in parasitism-percentage have been made for parasites of caterpillars defoliating teak, shisham and associated plants. Less in known about the value of braconid parasites of borers; wood-borers are not often highly parasitised; shoot-borers are rarely attacked. Some of the parasites of defoliators can be artificially multiplied in large numbers for the purpose of colonisation, e.g., *Cedria paradoxa*, *Cremnops desertor*. Some of the species parasitising defoliators of teak and shisham have been introduced from one region to another in recent years, e.g., *Apanteles malevolus*, *Microgaster plecopterae* (Beeson and Chatterjee, 1935, 1939); 2 species of *Microbracon* have been used in the biological control of the predators of the lac insect.

LITERATURE ON BRACONIDAE:
Ayyar T. V. R., 1923, *Rep. Proc. 5th. Ent. Meet.*, Pusa, pp. 352-362, A catalogue of the braconid wasps described from the Indian region, (supplemented by Dover C., 1925, *Ent., Mitt.*, XIV, p. 39).
— 1928, *Mem. Dept. Agr. Ind.*, X, 3, pp. 29-60. pls v-xiv, A contribution to our knowledge of south Indian Braconidae, Part i, Vipioninae.
Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., 1, No. 6, pp. 106-138, 2 figs., 1 pl., On the biology of the Braconidae.
— 1939, *tit. cit.*, V, No. 5, Further notes on the biology of parasites of teak defoliators in India.
Lal K. B., 1939, *Ind. Journ. Ent.*, I, pp. 52-58, figs. 4-7, Some new species of Hymenoptera from India.

Aivalykus eclectes is parasitic on *Sphaerotrypes siwalikensis* and *Sphaerotrypes* spp. (Scolytidae). **A. spherches** on *Phloeosinus* spp. (Scolytidae).

Agathis bischoffi is parasitic on the caterpillar of *Holcocera pulverea* (Blastobasidae).

The genus **Apanteles** consists of numerous species of black and yellowish wasps (about 1/16th of an inch long) the larvae of which are internal parasites of lepidopterous caterpillars. The female lays one to several eggs beneath the skin of the caterpillar. In the first instar the larva possesses strong sickle-shaped mandibles, presumably in order to feed on the fat-body of the host, whilst the following instar has weakly developed mandibles and the nourishment is mainly fluid. The last instar has again strongly built mandibles which are useful in cutting a way out through the skin of the host. At the anal end of the body is a swollen vesicle used in respiration. The mature parasitic larvae leave the host, which is usually still living, and pupate alongside in closely woven coccons of white or yellow silk which are spun in the course of a few hours. The number of parasites maturing per host ranges from one to several hundreds according to species; in the large colonies the cocoons are usually arranged in parallel or radial rows.

Apanteles acherontiae, black with femora, tibiae, and antennal scape reddish-yellow, 2·2 to 2·5 mm., parasitises the caterpillars of *Acherontia styx* and *A. lachesis* (Sphingidae). The cocoons are clustered together in a large white silky mass of 700 to 900 individuals. **A. bambusae,** 2 mm., black with parts of the legs red-testaceous, on *Cosmopteryx bambusae* (Cosmopterygidae).

A. cacao on *Lymantria ampla* (Lymantriidae). **A. cajani** bred from *Clerodendron infortunatum* attacked by *Dihammus cervinus* (Cerambycidae). **A. colemani,** 2 mm., black with red legs, on the caterpillar of *Orgyia postica* (Lymantriidae).

A. effrenus on *Caviria ochripes* (Lymantriidae). **A. fakhrulhajiae,** black with legs and underside of abdomen yellow, on *Holcocera pulverea* (Blastobasidae). 1935, *Ind. For. Rec.*, Ent. Ser., I, 6, p. 111, p. 137.

A. glomeratus, a European species, 3 mm., parasitises *Pieris brassicae*, the cabbage defoliating caterpillar, in North India also;

over 100 parasites may mature in a single caterpillar forming a mass of yellow cocoons.

A. heterusiae on the caterpillars of *Hypsa alciphron* (Hypsidae) and *Heterusia cingala* (Zygaenidae); about 3 parasites develop per caterpillar. **A. hyblaeae,** 2·5 mm., parasitises *Hyblaea puera* (Hyblaeidae) in Burma and Java. The life-cycle is 14 to 16 days in September (incubation and larval period 11 days, cocoon-period 5 days). Several cocoons, 11, are produced from one host. This is one of the species imported from Burma to Nilambur in 1937.

Beeson and Chatterjee S. N., 1939, *Ind. For. Rec.*, Ent., v, No. 5, p. 369 and Garthwaite P. F. and Desai M. H., 1939, *tit. cit.*, No. 4, p. 320.

A. hypsipylae, 2·5 mm., on *Hypsipyla robusta* (Pyralidae). **A. importunus,** 2·0 mm., on *Nephopteryx rhodobasalis* (Pyralidae). The pupal period lasts 5 days in the monsoon season and is prolonged to 12-30 days in the cold weather and spring in north India; the white cocoon is solitary, one from each host.

Apanteles machaeralis.

The adult is 2·5 to 2·7 mm. long, black with portions of the legs red-testaceous and resembles *A. puera.* The egg and larval stages are described and figured by P. N. Chatterjee, 1939, pl. I, figs. 4, 7–16. The cocoon is 3·6 to 4 mm. long, white. It is a solitary endoparasite of the caterpillar of *Hapalia machaeralis* (Pyralidae) which is attacked in the 1st to 3rd instars usually at about 3 or 4 days old.

Life-history: The maximum number of offspring produced in the laboratory by one mated female is 114. In north India the egg hatches in 24 hours. The larval period is 5 to 6 days and the cocoon-stage is 3–4 days in June, total life-cycle 9–11 days. The subsequent generations in July, August and September have a life-cycle averaging 12 to 13 days (larva 7 days; pupa 5 or 6 days), the longer development occurring in August when there is a drop in maximum temperature. In October the cocoon-period is 9 to 14 days and in November 9 to 17 days, which is prolonged to 27 days in December. The total life-cycle in the cold season extends to two months. In south India the earliest generations have a cocoon-period of 4 days in May and 6 days in June. In Burma the average minimum total life-cycle is 10 days in April–May and the average maximum 18 days in December-January the range being 8 to 26 days. The adults live on an average for 7 days or upto 26 days in the cold season.

This species is a regular specific parasite of *H. machaeralis.* In India the sequence of its generations is more rapid than but closely follows that of its host with a tendency to prolong its activity longer into the cold weather and to hibernate for a shorter time. In Burma 19 generations have been bred in a year in the laboratory compared with 13 for the host. The acceleration of the parasite is mainly during the hot weather and early monsoon

when the life-cycles of the parasite and host are 8 and 18 days respectively; in the winter the periods are 26 and 31 days. It ranges from Nilambur to Burma and has numerous hyperparasites. The percentage of the host-population destroyed by this species varies very considerably; it is usually rather low and the maximum recorded for one sample is 26 percent of the larval population.

LITERATURE:

Beeson and Chatterjee S.N., 1935, *Ind. For. Rec.*, Ent., 1, No. 6, pp. 112-115, fig. 1 (adult), On the biology of the Braconidae.

Garthwaite P. F. and Desai M. H., 1939, *tit. cit.*, v, No. 4, pp. 315-319, On the biology of the parasites of the teak defoliators in Burma.

Beeson and Chatterjee S. N., 1939, *tit. cit.*, v, No. 5, pp. 361, 368, Further notes on the biology of parasites of teak defoliators in India.

Chatterjee P. N., 1939, *tit. cit.*, v, No. 6, pp. 381-395, pl. 1, figs. 16, On the biology and morphology of Apanteles machaeralis Wlkn.

— 1938, *Univ. Allahabad Studies*, Zoology section, Cytoplasmic inclusions in the oogenesis of Apanteles machaeralis Wlkn.

Apanteles malevolus is an endo-parasite of *Hyblaea puera* in the 2nd and 3rd instars, i.e., when 3 to 6 days old, up to 50 parasites developing in one host-caterpillar, and emerging to spin up sulphur-yellow cocoons alongside. The life-cycle is 12 days in October–November. The following generation (in north India) passes the winter as a pupa hibernating in the cocoon for an average period of 115 days and emerging in March after the *puera* moths have resumed activity. This species is indigenous in Burma and in north India where it is heavily hyperparasitised. It is one of the species imported from Burma to Nilambur in 1937 and 1938; liberations were made in Nilambur in 1938.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., 1, No. 6, pp. 115, 116, On the biology of the Braconidae.

Garthwaite P. F. and Desai M. H., 1939, *tit. cit.*, p. 319, On the biology of teak defoliators in Burma.

Beeson and Chatterjee S. N., 1939, *tit. cit.*, p. 369, Further notes on the biology of parasites of teak defoliators in India.

A. mendosae on *Dasychira mendosa* (Lymantriidae). **A. obliquae**, 2–3 mm., black with the base of the antennae, femora and tibiae and parts of abdomen light red, parasitises *Diacrisia obliqua* (Arctiidae). Up to 25 wasps may mature per host-caterpillar; the pupal period is completed in less than a week in south India.

A. papilionis parasitises swallowtail butterfly caterpillars, *Papilio demoleus*, *P. polytes*, *P. sarpedon*; up to 200 individuals may mature in the body of one host. **A. phycodis**, 2·8 mm., on *Phycodes radiata* (Glyphipterygidae). **A. puera**, 2·5 mm., black with the front and middle legs reddish, on *Hyblaea pucra* (Hyblaeidae). As many as 15 parasites develop in one host. The pupal period is 5 days in October and 9 days in November. Known only from Bengal and Burma.

A. ruidus, 2·0 to 2·5 mm., black, antennae brown, legs mainly reddish-testaceous, on *Hapalia machaeralis* and *Pyrausta celata-*

lis (Pyralidae). In northwest India the larval period is 16-20 days and the pupal period 12-18 days in November-December and as much as 24 days in January. In Central India the life-cycle is shorter with pupal period of 6 days in September. Up to 14 parasitic larvae emerge from one host and spin greenish-white cocoons under the crescent web of the hibernating host-caterpillar. It occurs in central and north India.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., 1 No. 6, pp. 117, 118, On the biology of the Braconidae.

A. ruficrus, 2 mm., on *Hypsipyla robusta* (Pyralidae) and *Periga capensis*, *Agrotis* (*Rhyacia*) *ypsilon* and *Spcdoptera mauritia* (Noctuidae). This species ranges from India to Australia. **A. salutifer** on *Margaronia pyloalis* (Pyralidae).

Apanteles stantoni, 2·3 mm., black with legs bright red or yellowish-red on *Margaronia laticostalis* (Pyralidae) throughout India and Burma. The larval period is about 7 days and the pupal period of 4 to 6 days in July-November, lengthening to a larval period of 15 to 20 days and a pupal period of 25 to 30 days in January-February. 18 to 36 parasites may develop in one host. Over 50 percent of the larval population may be parasitised. Its alternative hosts are *Botyodes asialis*, *Jocara malefica*, *Margaronia glauculalis*, *M. pomonalis*, *M. vertumnalis*, *Sylepta balteata* (Pyralidae), *Argyroploce codonectis* (Eucosmidae) and *Giaura sceptica* (Noctuidae). **A. stauropi** on *Stauropus alternus* (Notodontidae).

A. tachardiae, 3 mm., black with parts of the legs reddish-testaceous, on the nearly mature larva of *Holcocera pulverea* (Blastobasidae) and of *Ephestia* (Pyralidae) both of which feed on lac. Only one parasite develops in each caterpillar, and emerges when full grown from a hole in the lateral or neck region to spin a cocoon of white silk, 4 mm., close against the body of the host. The emergence of parasites from lac is greater in July-August, October-November and January-March, corresponding with the maturation-periods of the lac crops and the periods of greatest emergence of the host, *Holcocera pulverea*. February, March is the most important emergence-period. Adults have been kept alive for 25 to 55 days in the cold season, November to January, the females living longer than the males. Although an important endoparasite of the lac predator the average percentage-parasitism caused by it is about 5; the monthly maximum percentage-parasitism is 16-25.

Annual Reports of Indian Lac Research Inst., from 1931-32 and onwards.
Misra M. P. and Gupta S. N., 1934, *Ind. Journ. Agr. Sci.*, IV, p. 860, Biology of Holcocera pulverea Meyr. (Blastobasidae) and its parasites.
Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 6, pp. 119, 138.

A. taprobanae on *Stauropus alternus* (Notodontidae). **A. taragamae** on *Taragama dorsalis* (Lasiocampidae) and other species.

Two species of **Apanteles** as yet unnamed are common parasites of *Dichomeris eridantis* (Gelechiidae) and are abundant in shisham plantations from May to August.

Aphrastobracon flavipennis is a solitary ectoparasite of the caterpillars of *Eublemma scitula* (Noctuidae) an enemy of Coccidae including *Anomalococcus indica*, *Aspidiotus orientalis*, *Pulvinaria maxima*, and *Laccifer lacca*. It is occasionally parasitic on the older larvae of *Eublemma amabilis* in the major lac-growing areas. The adults are very long lived (over 100 days), e.g., from October to January. Eggs laid in October, November produce adults in about 3 months. The egg, larva (5 instars) and pupa are described by Glover.

Glover P. M , 1939, *Ind Journ. Ent.*, I, pp. 1-14, fig. 1, Notes on the biology and larval growth of A. flavipennis.

Atanycolus initiator parasitises the larva of *Tetropium oreinum* (Cerambycidae) in the sapwood of *Cedrus deodara* emerging in June. In Europe it attacks Cerambycidae and Sesiidae.

Bracon urinator parasitises the larva of *Larinus saussureae* (Curculionidae) emerging in April; in Europe it also parasitises *Larinus* and other weevils.

Camptothlipsis furtifica, reddish-testaceous, 4–4·7 mm., on *Dichomeris eridantis* (Gelechiidae), and is active in shisham plantations between March and September. The colourless ovoid egg is inserted within the body of the young caterpillar. Before it is full fed the parasitic larva issues from the host and continues to feed externally till the body of the caterpillar is dried up. The larval period is 7 or 8 days in June. An oval white cocoon, 7 × 2 mm., is spun alongside, the spinning taking 12–18 hours; the prepupal stage lasts about 12 hours and the whole cocoon-period lasts 5 to 12 days in April–August. The whole life-cycle is completed in 14 or 15 days in June. Parasitism has not been recorded to exceed 8 percent.

Cardiochiles adina is an internal parasite of the caterpillar of *Dirades theclata* (Epiplemidae), one parasite maturing in each host. In August the cocoon-stage is nine days at which season the pupal period of the host is six days.

Cedria anomala is a rare parasite of the larva of *Hapalia machaeralis* in Burma, gregarious in the cocoon-stage like *Cedria paradoxa*. The life-cycle takes 18 days in January.

Cedria paradoxa

The normal wild host of this species appears to be *Margaronia pyloalis* (Pyralidae) on which it occurs in north India and China. But it readily breeds in the laboratory on numerous species of Pyralidae, viz., *Agrotera basinotata*, *Botyodes asialis*, *Hapalia machaeralis*, *Lamprosema diemenalis*, *Lygropia obrinusalis* and *L. quaternalis*, *Lamida* sp., *Maruca testulalis*, *Margaronia hilaris*, *Pilocrocis milvinalis*, *Pyrausta coclesalis* and *P.*

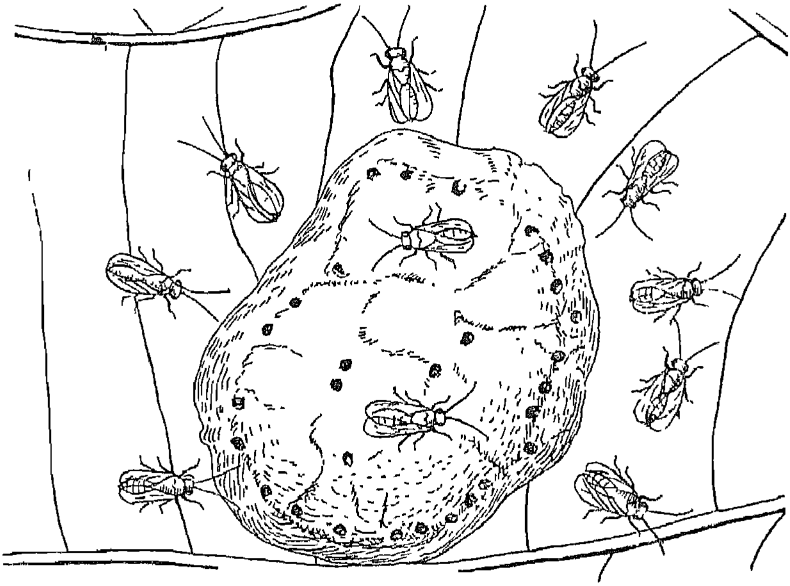

Fig. 135. Communal pupal cocoon of Cedria paradoxa on a leaf of teak (enlarged about 8 times) showing exit-holes and emerged wasps congregated for a while before dispersing.

celatalis, *Sylepta balteata*, *S. sabinalis*, and *S. lunalis*; also *Cacoecia epicyrta* (Tortricidae), *Dichomeris eridantis* (Gelechiidae).

Life-history: The female is testaceous-red, with the apex of the antenna darker, 2·2 mm.; the male is 1·5–1·8 mm. On discovering the host-caterpillar the female reduces it to inactivity and in the course of 24 hours it becomes completely paralysed; eggs are laid in clusters of up to 26 on the undersurface. Ordinarily only one caterpillar is parasitised by one female but under laboratory conditions oviposition can be induced on several hosts and up to 100 eggs may be laid. On hatching the parasitic larvae scatter and feed externally at punctures in the skin of the caterpillar. While the larvae are growing the female *C. paradoxa* remains guarding the brood and she also remains on the spot after the larvae have pupated and until the young adults emerge. Before forming their cocoons the larvae prepare a more or less circular sheet of brownish-white silk attached at its circumference to the leaf and forming a low domed shelter. The flies emerge independently each cutting a circular hole in the sheet-web. Fig. 135 shows the web, the exit-holes and some of the emerged wasps congregated for a while before dispersing. The life-cycle is 11 days in September (egg 1 day, larva 4 days, pupa 6 days) 13 in

October, 21 in November, and 33 in December, January. The total life-cycle at 75° F. including mating and oviposition is 11 to 15 days. Under normal conditions the length of life of the female exceeds the period of the life-cycle. She may live for 21 days at 86° F., 110 days at 52° F. and 155 days in cold storage.

Colonisation: This species was the first parasite to be used for the improvement of the natural control of defoliators of teak plantations in India and Burma. It has been regularly bred at Dehra Dun whence colonies have been supplied to south India and Burma for the control of *Hapalia machaeralis* and to the Punjab for *Margaronia pyloalis*. In 1937 over 40,000 adults were released in 11 localities in Nilambur teak plantations and 15,000 in Changa Manga shisham-mulberry plantation in the Punjab. A consignment of 500 parasites sent to Burma formed the stock from which 200,000 adults were reared and liberated in 170 localities during the years 1937-1940. Recoveries of *Cedria paradoxa* have been made subsequently in places where colonies were released, viz., in 2 centres in Nilambur in 1937 and 1938, and in 5 centres in Burma in 1938 and 1939 from *H. machaeralis* and also in 2 instances from *Maruca testulalis* and a phycitine barkborer.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., 1, No. 6, pp. 120-125 pl. 1.
— 1939, *tit. cit.*, v, 5, pp. 371-373.
Ann. Rep. For. Ent., Burma, for 1939-40.

Cenocoelius eous on the larvae of wood and bark-boring larvae of small Cerambycidae (e.g., *Desisia*, *Exocentrus*, *Glenea*, *Mesosa*, *Pterolophia* spp.).

Chelonus cycloporus on the larva of *Holcocera pulverea*. See Mahdihassan, 1939, *Current Science*, p. 104 for figure of adult.

Cremnops desertor

A European and north Asiatic species parasitic in India and Burma on *Hapalia machaeralis*; local or geographical races probably occur. [fig. 136].

Life-history: Second and third instar host larvae are attacked by this solitary endoparasite and emergence for pupation occurs from the prepupal stage of the host. The egg and larval stages vary from an average of 10 days in April to 17 days in December, the maximum being 35 days. The larva when it emerges is bright yellow. The cocoon or pupation occurs within the web of the host. The pupal period varies from 6 to 14 days. The total life-cycle thus corresponds fairly closely to that of the host and there is a sequence of 12 to 14 generations a year. This species has been multiplied in the laboratory (in Burma) and a progeny of 223 cocoons has been obtained from the oviposition of one female. It is one of the species that was shipped from Burma to Nilambur in cold storage and by air mail in 1937 and 1938. Although of wide distribution *C. desertor* is only occa-

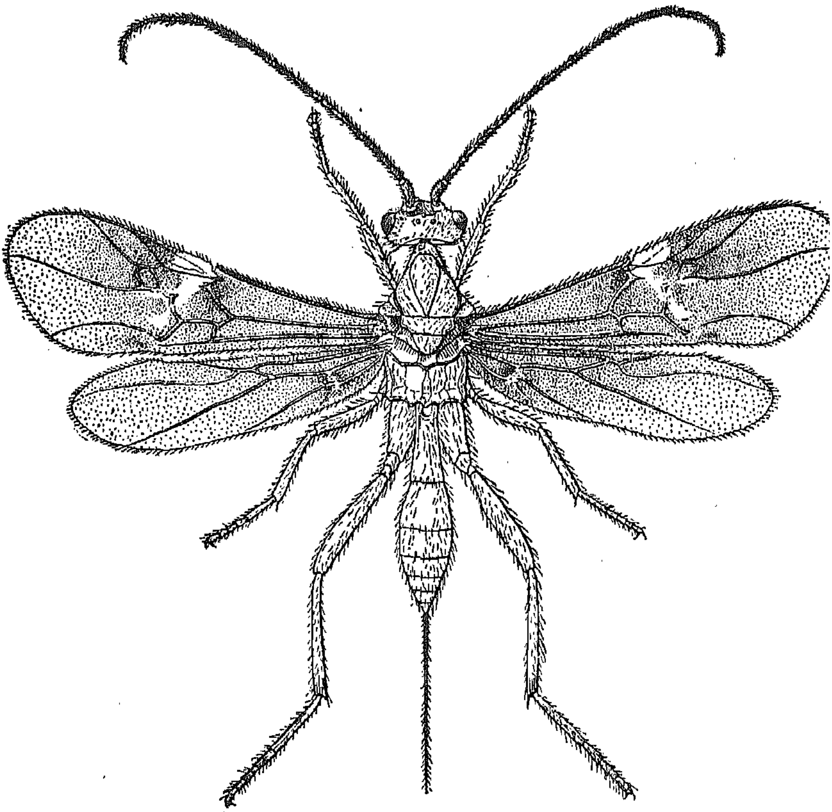

Fig. 136. Cremnops desertor, natural size 7·5 mm.

sionally evident; it is indigenous in Burma, United Provinces and Madras.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 6, p. 125.
Garthwaite P. F. and Desai M. H., 1939, *tit. cit.*, v, No. 4, pp. 328, 330, fig. 3.
Beeson and Chatterjee S. N., 1939, *tit. cit.*, v, No. 5, pp. 373, 374.

Dinocampus mylloceri is a parasite of the adult of *Myllocerus undecimpustulatus maculosus* (Curculionidae). The female *Dinocampus* inserts an egg at the apex of the abdomen of the weevil. The parasitised weevil shows no signs externally of being attacked and does not die until the parasite larva leaves the body by the rectum and pupates in a cocoon.

Trehan K. N., 1929, *Agr. Res. Inst. Pusa*, Bull. 181, pp. 25, 26, pl. v, figs. 1–6 (as *Loxocephalus*): Report of the Imperial Ent. for 1928-29, *Agr. Res. Inst. Pusa*, pp. 68, 69, pl. I, figs. 1-6.

Disophrys sissoo

An endoparasite of the 2nd instar caterpillar of *Plecoptera reflexa* (Noctuidae). The adult has a yellow body, infuscate wings with the costa black, length 6–7 mm. The egg is rapidly laid inside the body of the caterpillar. The full grown larva, 6×2 mm., has a clearly segmented body ringed with short spinules, 9 pairs of spiracles, and mandibles with 18 serrations. When full fed it issues from the host in the 4th instar, the colour of which has changed from green prematurely to pink, and usually falls to the ground. The cocoon is glossy white, loosely woven, cylindrical, 8·5 to 10 mm.×3·5 to 4 mm., spun alongside in rubbish in the soil. One parasite develops in each host. Emergence follows the cutting of a circular hinged cap.

In May the life cycle is 15 days (incubation 2 days, larval period 6, cocoon 7). The cocoon-stage is 10 days in March, 5 days in May, 6–8 days in June, July, 7 or 8 days in August. In September adults live for about 18 days. In May, June the maximum percentage of parasitism recorded is 15. It is less abundant than *Microgaster plecopterae* in the shisham plantations of the Punjab. The parasitism-percentage of *P. reflexa* is normally low but may rise to 30 percent. Colonisation in some of the shisham plantations in Multan division, Punjab, was tried in 1938 and 1939. The species occurs with *Dalbergia sissoo* and elsewhere in India; it may possibly be a subspecies of the African *Disophrys lutea*. An alternative host is *Pandesma quenavadi* (Noctuidae).

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 6, p. 126.

Disophrys tuberculatus on the pupa of *Trabala vischnou* (Lasiocampidae).

Doryctes coxalis on the larva of *Xylotrechus smei* (Cerambycidae) emerging in August–November. **D. strioliger** on the larva of *Chlorophorus annularis* and *Xylotrechus quadripes* (Cerambycidae). Several *Doryctes* larvae feed externally on one *Xylotrechus* larva and pupate gregariously in cocoons in the tunnel of the borer. The adult has a yellow head and dark body and lives 25 days to 2½ months. It is the most efficient of the parasites of the coffee stem-borer in Cochin China; occurs in north India but has not been recorded from south India. **D. tristriatus** on *Xylotrechus quadripes* and *Chlorophorus annularis* (Cerambycidae). One *tristriatus* larva feeds externally on one *Xylotrechus* larva and pupates in an elongate cocoon in the bore-tunnel. The adult has a red head and thorax with a dark abdomen banded with white beneath.

Euagathis cryptophlebiae on the fruit-borer, *Argyroploce illepida* (Eucosmidae).

Exobracon maculipennis. A large (½ to 2/3rds of an inch) yellow wasp with dark apices and 2 or 3 black spots on the wings and an ovipositor over an inch long, parasitic on the larvae of the

larger timber-boring Cerambycidae, e.g., *Aeolesthes holosericea*, *Hoplocerambyx spinicornis* and *Plocaederus obesus*. Eggs are presumably laid on or near the larva in the tunnel in the sapwood. After feeding on the host, which continues to live to the last instar, the parasites pupate in its already formed pupal chamber. As many as fourteen closely packed cocoons may occur in one chamber. The wasps in one bundle of cocoons mature simultaneously and emerge in single file to take flight at once. The adult occurs on the wing between October and May but most numerously in the spring months. The species increases abundantly in epidemics of *Hoplocerambyx spinicornis* but is not of great importance in controlling the borer.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 6, On the biology of the Braconidae.

Fornicia ceylonica is parasitic on *Natada nararia* and *Parasa lepida* (Limacodidae).

Iphiaulax immsi. This species has been frequently bred from logs of *Shorea robusta* attacked by Cerambycidae; emergences occur in April–July and September–October. There are probably two generations in the year. It is parasitic on the larvae of *Xylotrechus smei* and possibly also on the young larvae of *Aeolesthes holosericea* and *Hoplocerambyx spinicornis* (all Cerambycidae). Pupation takes place in a flat lozenge-shaped cocoon under bark and never in the pupal chamber of the larger borers.

Macrocentrus homonae, a parasite of the Tea Tortrix, *Homona coffearia*, was introduced from Java to Ceylon in 1935 and became well established in 2 or 3 years with a high parasitism-percentage several times that produced by indigenous species of parasites. The life-cycles of the host and parasite occupy about 10 and 7 weeks respectively and *M. homonae* survives the southwest monsoon season when the host is scarce. This introduction has modified the pest situation and may make it possible to abolish compulsory control.

King C. B. R., 1937, *Tea Quart.*, X, pp. 187-190, The longtailed parasite of the tea tortrix.
— 1939, *tit. cit.*, XII, pp. 86-91, Tortrix control.

Macrocentrus philippinensis is an internal parasite of the caterpillar of *Botyodes asialis* (Pyralidae) one individual developing in each host. Hibernation occurs in the cocoon-stage for four to five months. **M. trimaculatus** on *Lygropia quaternalis* and *Sylepta lunalis* (Pyralidae), one parasite developing in each caterpillar and emerging to form an elongate light brown cocoon within the rolled leaf of the food-plant. The pupal period is 13 days in May–July.

Megarhogas theretrae on *Theretra celerio* and other Sphingidae. As many as fifty parasites develop in the body of one host-caterpillar and pupate inside its distended larval skin.

Meteorus dichomeridis on *Dichomeris eridantis* (Gelechiidae).

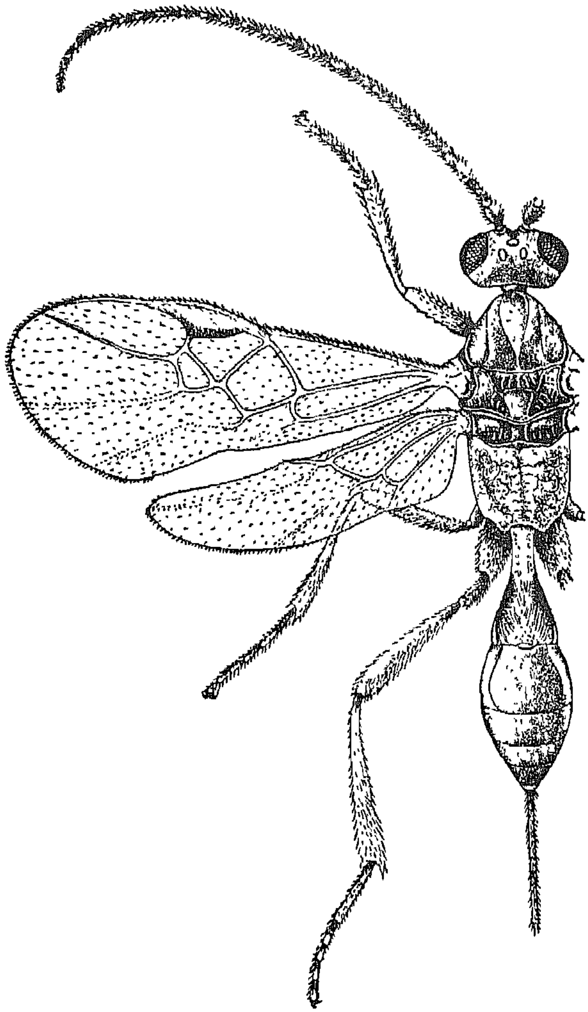

Fig. 137. Meteorus dichomeridis, female 4 mm.

The adult female, 4 mm., is shown in figure 137. The yellowish stalked egg is inserted within the body of the caterpillar and one parasite matures in each. The spindle-shaped brownish cocoon, 5 × 2 mm., is formed near the host's body and the *Meteorus* adult escapes by cutting a hinged conical cap. The cocoon-period lasts 4 to 8 days during April–August in the shisham plantations in the Punjab and slightly longer at Dehra Dun. It appears with the first generation of *Dichomeris* in February or March and the parasitism-percentage may rise to 26 by May but the average over the whole season is low.

Microbracon greeni

This is an orange-yellow braconid with a black patch on the metathorax and on the abdomen, 3 to 6 mm. long. It is an important ectoparasite of the larvae of *Eublemma amabilis* (Noctuidae), a lac predator, and *Earias fabia* (Noctuidae), the spotted bollworm of cotton. A coloured plate has been issued by the Agricultural Research Institute (under the old name *Rhogas lefroyi*; also *Microbracon lefroyi*).

Life-history: The egg is less than a millimeter long and is laid externally on the body of a caterpillar of *E. amabilis* of the 5th to 10th instars. As a rule only one egg is laid on each host-caterpillar of the 5th and 6th instars, but more eggs up to 11 may be laid on 7th to 10th instar larvae of *Eublemma*; 8 parasites have been bred from a 10th instar larva. The average number of eggs laid per female reaches a maximum of about 80 in the season August–November. The parasitic larva on hatching attaches itself by its mouth to the body of the host and feeds by suction. It may remain at the original point of attachment for the whole of the 1st instar but usually migrates to a new place. There are 5 larval instars (described by P. M. Glover, 1934, *Bull. Ent. Res.*, 25, pp. 521–539, 7 figs.), which occur in two size-series representing the male and the female, but the series overlap. The larva of *M. greeni* feeds externally until full grown when it is 3 to 4 mm. long. Pupation takes place at the side of or below the remains of the host in a thick white silken cocoon, about 3 or 4 mm. long.

The total life-cycle is 8 to 10 days in March–May (egg 1 day, larvae 4–5 days, pupa 3–4 days), 9 to 12 days in June, 10 to 11 days in July, 9 to 12 days in August, 9 to 14 days in September, 20 to 25 days in October-November, 35 to 40 days in the cold weather, 25 days in January and 21 in February. There are 20 generations possible in a year, the normal variation being around 14. The adults live 2 to 6 weeks, females being longer lived than males, and the maximum longevity occurring in the season October–December. The average parasitism by *M. greeni* for the whole year is in the neighbourhood of 7 percent and may reach a maximum of 30 percent in December.

The race *lefroyi*, parasitic on the spotted bollworm of cotton, can complete its life-cycle in 7 to 28 days at temperatures of 30° to 16° C., which is more than twice as fast as the development of its host; under the most favourable conditions it can theoretically complete 35 generations a year. The pre-imaginal development and viability under different conditions of temperature and humidity have been studied by Taskir Ahmad and Ghulam Ullah.

LITERATURE:

Annual Reports of the Indian Lac Res. Inst., for 1931-32 onwards.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 6, pp. 129, 137. On the biology of the Braconidae.

Lal K. B., 1939, *Curr. Sci.*, VIII, 3, pp. 125, 126, (Identity).

Ahmad T. and Ullah G., 1939, *Ind. Journ. Ent.*, I, pp. 17-47, Ecological studies on the spotted bollworms of cotton and their parasites.

Microbracon hebetor parasitises caterpillars breeding in stored grain and flour, dried fruits, lac, etc. and in consequence has been widely distributed to sea-ports in various parts of the world, but it has not spread so readily inland. It occurs in Ceylon and at a few places in India. Its hosts are *Antigastra catalaunalis*, *Corcyra cephalonica*, *Ephestia cautella*, *E. kuhniella*, *Galleria mellonela*, *Plodia interpunctella*, *Pyralis farinalis* (Pyralidae), also *Earias* spp., *Eublemma amabilis*, *E. scitula*, *Heliothis armigera*, *Laphygma exigua*, (Noctuidae), *Holcocera pulverea* (Blastobasidae).

The life-history of this species as a parasite of the predators of the lac insect has been studied at the Indian Lac Research Institute. The female, 5 mm., bites through the covering of lac or silk-web protecting the *Eublemma* or *Holcocera* caterpillar, stings the host and lays eggs, which are 0·56 mm. long, on or close to the host. During stinging a neuro-toxin appears to be injected, paralysis occurs and movements are arrested, but the heart continues to beat slowly for some time. The average number of eggs laid per *E. amabilis* larva is 8, per *H. pulverea* larva 6 and per *E. scitula* 5. Of parasitised host larvae 40 to 60 percent fail to give rise to adults and from the remainder 2 or 3 adults mature in each host. The *Microbracon* larvae feed externally on the host. The life-cycle varies from 10 to 18 days (egg 1 day, larval feeding 2 or 3 days, in cocoon 3 days, pupal period 3 to 5 days). In the laboratory 23 generations have been bred serially during one year. The males and females live for a few days to one month ; a fertilised female lays about 40 eggs. For Ceylon the life-cycle at an average temperature of 72° F. is about 18 days. At Delhi the life-cycle is 35 days at 16° C. and 6 days at 35° C. constant temperature. It has a higher upper vital limit than *M. greeni*. *M. hebetor* has been used in the biological control of the predators of the lac insect, *Laccifer lacca* (Coccidae); colonies of this parasite together with *Microbracon greeni* were bred at the Lac Research Institute and have been released in lac growing areas in Bihar (see further details in chapter on Biological Control).

Glover P. M. and Chatterjee K. C., 1936, *Proc. Ind. Acad. Sci.*, III, pp. 195-211, figs. 1, 2, pl. II.
Annual Reports of the Indian Lac Res. Inst. from 1936-37.
1940, *Ann. Rep. Imp. Agr. Res. Inst.*, New Delhi, 1938-39, p. 123.

Microgaster indicus. An internal parasite of the mature caterpillar of *Hapalia machaeralis* (Pyralidae), one individual developing in each host. The cocoon is formed outside near the body of the caterpillar. The cocoon-stage lasts 8 days in September, 13 in November and is prolonged to at least 34 days in December, January. India and Burma, not common.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 6, p. 130.
Garthwaite P. F. and Desai M. H., 1939, *tit. cit.*, V, No. 4, p. 341.

Microgaster kuchingensis on *Pyrausta coclesalis* (Pyralidae).

M. plecopterae is apparently a specific parasite of the shisham defoliator, *Plecoptera reflexa* (Noctuidae), in the irrigated plantations of the Punjab and in north India. One parasite develops internally in each host which is attacked in the second instar. Pupation occurs in a barrel-shaped cocoon, 4·5 mm., formed in the soil debris after emergence from the moribund third instar caterpillar which falls to the ground. The length of the cocoon-stage is 6–10 days in April, May, 5–10 days in June and 7–9 days in July–September. The full life-cycle lasts about 16–19 days. The parasitism-percentage rises as high as 60 in shisham plantations but is on the average low. Introductions of *M. plecopterae* to the younger shisham plantations in the Punjab were made in 1938–1939.

M. psarae on *Acharana mutualis*, *Lygropia quaternalis*, *Sylepta balteata* (Pyralidae). **M. tomentosae** on *Lamida carbonifera* (Pyralidae). Several individuals develop in one host.

Microplitis maculipennis on *Achaea janata* (Noctuidae), one individual developing in one host. The cocoon is ashy grey and usually formed at the tail end of the caterpillar attached to the undersurface of the last free segments.

Lefroy H. M., *Mem Dept. Agr., Ind.*, II, p. 73, pl. VII, fig. 7 (unnamed).
Ramakrishna Ayyar T. V., 1921, *Journ. Bomb. Nat. Hist. Soc.*, XXVIII, pp. 298-300, pl., figs. 1-6 (as *Microplitis ophiusae*).

Microplitis similis is parasitic on the cutworm, *Agrotis ypsilon* (Noctuidae). The female inserts the egg just under the skin of the caterpillar. As many as 60 parasitic larvae may develop in one host, reaching a length of about 5 mm. when full sized. In the cold weather months in the plains the length of the egg stage plus larval stage is 4 to 7 weeks, which is reduced in March to about 17 days and in April to about 12 days. The mature larva emerges part way through a puncture in the skin of the caterpillar and begins to spin its cocoon. All the parasites emerge together and spin up and the dead body of the host becomes covered with a loose heap of cocoons. The pupal stage lasts for 17 days in December and 8 days in March. The wasp emerges by cutting a circular disc at one end of the cocoon. There is a succession of broods from about September to April after which, when the mean temperature rises above 85° F., the larva aestivates in the cocoon. The parasitism of its host, *Agrotis ypsilon*, in the plains may rise to 70 percent. The life-history is described by Dutt H. L., *Rep. Proc. Fourth Ent. Meeting*, Pusa, Feb. 1921: (1921) pp. 157–163, 2 pl.

Phanerotoma buchneri on the caterpillar of *Holcocera pulverea* (Blastobasidae), predaceous on the lac insect *Laccifer lacca*.

Phanerotoma hendecasisella.

A parasite of the larvae of *Dichomeris eridantis* (Gelechiidae), *Earias insulana*, *Emmalocera depressella*, *Hapalia machaeralis*,

Hendecasis duplifascialis, *Hypargyria metalliferella*, *Hypsipyla robusta*, *Lygropia quaternalis*, *Maruca testulalis*, *Margaronia pyloalis*, *Nephopteryx rhodobasalis*, *Pilocrocis milvinalis*, *Pyrausta aureolalis*, *Salebria strigivenata*, *Sylepta balteata*, *S. derogata*, (Pyralidae), *Pammene theristis* (Eucosmidae). It does not appear to be particular in the choice of a host although tending to parasitise those of which the caterpillars are sheltered in a bud or leaf-roll or under a web.

The cocoon-period lasts 6 to 7 days in April. During July–August the life-cycle is about 25 days with a cocoon-period of 8 to 15 days. In September–November the cocoon-period is 10 to 20 days. In the cold season the parasite hibernates within the host and does not emerge until March (in north India). The cocoon-stage in March is 10 to 20 days. It occurs as a parasite of *Hapalia machaeralis* in Burma and India, but not abundantly unless there is considerable mixed forest in the vicinity.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 6, pp. 132, 3, On the biology of the Braconidae.
Garthwaite P. F. and Desai M. H., 1939, *Ind. For. Rec.*, Ent., V, No. 4, p. 343.
Beeson and Chatterjee S. N., 1939, *tit. cit.*, V, No. 5, pp. 377, 8.

Sbeitla furax is a parasite of some of the borers of seasoned wood and bamboos belonging to the family Bostrychidae (i.e., several species of *Sinoxylon* and *Dinoderus*, *Heterobostrychus aequalis*, *Lyctus africanus*). The life-cycle is annual with emergence mainly in May to July, but is capable of being prolonged.

Spathius bisignatus is a fairly common parasite of "ghoon" borers of bamboo, *Dinoderus brevis*, *D. minutus*, *D. ocellaris* (Bostrychidae). The adult, 3 to 5 mm., reddish-brown is figured by Beeson and Chatterjee, 1935. Emergence occurs between March and October and is most abundant in July–August. The average percentage-parasitism of *Dinoderus* by *S. bisignatus* alone in bamboo-depots is not very high but it is one of the group of parasites of bamboo-borers that may increase under favorable conditions to an incidence at which the parasite-population out-numbers the borer-population and establishes control. The life-cycle conforms to that of the host and there are 3 generations a year, but, as in the case of the host, delayed development for 12–15 months may occur.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 6, pp. 133-135, fig. 2

S. cavillator on *Mecistocerus fluctiger* and other Curculionidae. Emergence occurs in May, June and November, December corresponding to the life-cycles of its hosts. **S. critolaus**, 2–3 mm., is normally wingless (vestigial) in both sexes. The larva is an ectoparasite of the older larvae of *Pempheres affinis* (Curculionidae) and will feed also on larvae of *Hypolixus* (Curculionidae) and *Sinoxylon sudanicum* (Bostrychidae). A female *critolaus* may lay over 50 eggs, one on each paralysed host larva. The life-

cycle varies from 12 to 28 days. Ayyar P. N. K., 1940, *Ind. Journ. Agr. Sci.*, x, v, p. 648. **S. elaboratus** on *Osphilia odinae* and *O. vitis* (Curculionidae) and *Diamerus* spp. (Scolytidae). Emergence occurs in April–June and November, December. **S. festinans** on *Camptorrhinus mangiferae* (Curculionidae). **S. generosus** on the barkbeetle *Scolytus major*. Emergence occurs between June and September.

Spathius vulnificus, 3–5 mm., on species of *Dinoderus*, *Lyctus*, *Heterobostrychus aequalis* and other bostrychid borers of dry wood; it is widely distributed in sawmills and wood-using industries in India. Emergence occurs throughout the year but is most abundant in April–July in north India in each of which months the number of individuals maturing lies between 10 to 20 percent of the total population of the year. It has been bred artificially on *Lixus truncatulus* and *Pempheres affinis* (Curculionidae) in south India where it has a life-cycle of 19–29 days. The adults may live for three months (in the laboratory). Egg-laying starts 4 days after pairing but may be delayed for 8 weeks; the eggs are deposited externally on or near the host-larva. One female can lay 90 eggs and parasitise 9 hosts, up to 28 eggs being laid on one host. Hatching takes place in about 2 days and the larva attaches itself to the body of the host where it feeds for about 4 to 7 days. A thin papery cocoon is spun in the tunnel of the borer in a cluster with those of the rest of the team. The prepupal stage in the cocoon lasts about a week and the pupal stage needs 6 to 13 days for complete maturation.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 6, pp. 136, 137.
Ayyar P. N. K. and Narayanaswami P. S., 1940, *Ind. Journ. Ent*, II, pp. 79-86, fig. 1, On the biology of Spathius vulnificus Wlk., a possible effective parasite of Pempheres affinis in south India.

Spinaria nigriceps is a parasite of *Belippa laleana* (Limacodidae).

Zele elagabalus is an endoparasite of the caterpillar of *Selepa celtis* (Noctuidae), one individual maturing in each host and emerging after the host's cocoon has been formed and before pupation. The larval period of *Z. elagabalus* is over 4 weeks in October and the pupal period is up to 3 weeks in November. **Z. infumator,** a European species, is parasitic on *Ectropis deodara* (Geometridae), emerging in June, July from the pupae of the host and forming a cocoon in the soil.

CHALCIDIDAE

ONE of the families of the CHALCIDOIDEA and the only unit to which the term 'chalcid' or 'chalcid fly' should be applied.

Mani M. S., 1938, *Catalogue Ind. Ins.*, Part 23, Chalcidoidea.
Pruthi H. S and Mani M. S., 1940, *Imp. Counc Agr. Res.*, *Misc. Bull.* No 30, Biological notes on Indian parasitic Chalcidoidea.
Waterston J, 1922, *Ind. For. Rec*, IX, ii, On Chalcidoidea mainly bred at Dehra Dun.

Antrocephalus destructor, a parasite of the larva of *Hypsipyla*

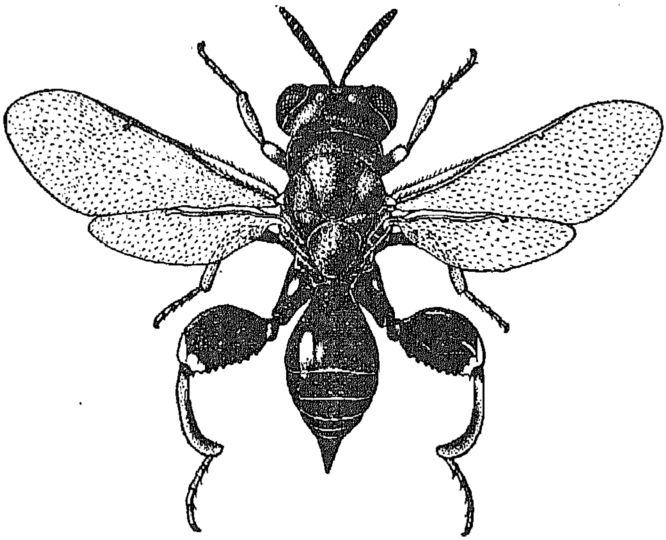

Fig. 138. Brachymeria euploeae, natural size 5 mm.

robusta (Pyralidae). It is not a frequent enemy of this insect and attacks caterpillars only when they are wandering freely before pupation. **A. renalis** on *Hypsipyla robusta* and *Tirathaba trichogramma*, emerging from the pupa. It attacks only the flower and fruit feeding generations of *H. robusta* (in north India) and has not been recorded from the shoot-boring generations.

Brachymeria argentifrons is a parasite of *Sarcophaga dux* (Calliphoridae) and pupae of Lasiocampidae. It is figured by Pruthi and Mani, 1940, fig. 4. **B. euploeae**, a common Indian species, also found in Australia, is a parasite of the pupae of *Hapalia machaeralis*, *Hypsipyla robusta* (Pyralidae), *Hyblaea puera* (Hyblaeidae), *Dasychira thwaitesi* (Lymantriidae), *Oreta carnea* (Drepaniidae), as well as of the butterflies *Euploea* spp. and *Virachloa isocrates*; also occasionally on the pupae of the moth predators of the lac insect. It is hyperparasitic on the teak defoliators through their braconid, ichneumonid and tachinid primary parasites. In Sumatra it was observed that the adult *B. euploeae* needs various nectar-yielding plants with extra-floral nectaries for optimum conditions. [fig. 138].

Garthwaite P. M. and Desai M. H., 1939, *Ind. For. Rec.*, Ent., v, 4, p. 321 and fig. 1 (adult).

B. hearseyi parasitises pupae of *Hypsipyla robusta* (Pyralidae).

B. nephantidis parasitises the pupae of *Dichomeris eridantis* (Gelechiidae), *Nephantis serinopa* (Xyloryctidae) and *Hapalia machaeralis* (Pyralidae). It is also parasitic on *Apanteles taragamae* (Braconidae).

Beeson and S. N. Chatterjee, 1939, *Ind. For. Rec.*, Ent., v, No. 5, p. 370.

B. nursei parasitises the prepupal larvae and pupae of *Plecoptera reflexa* (Noctuidae) and is occasionally hyperparasitic through the tachinid parasites of the defoliator. The female searches out pupae on the ground, among leaves and in the soil. One egg is normally laid in the host and one parasite matures. About 20 eggs are laid by one female in the course of a week. The full grown larva is yellowish grey and about 9 mm. long; it pupates within the hollowed pupal shell of the host and the wasp emerges by cutting an irregular hole near the anterior end of the pupal skin. The life-cycle from egg-laying to emergence is 9–16 days in July. The wasps live for about 2 weeks and mating may take place on the first day of life. *B. nursei* is evident from April to August in several generations. The percentage-parasitism of *P. reflexa* in shisham plantations may rise to 40–50 percent in June and 55 percent in July.

B. obscurata is a parasite of the pupae of *Lygropia quaternalis* and *Maruca testulalis* (Pyralidae), also *Hyblaea puera*, *Orgyia thwaitesi* (Lymantriidae), *Platyedra gossypiella* (Gelechiidae). It is also hyperparasitic on *Lygropia quaternalis*, through *Eutorocca fasciata* (Tachinidae) and braconids and icheumonids. A subspecific form is a parasite of the pupa of *Ectropis deodarae* in deodar forests.

Beeson and Chatterjee S. N., 1939, *Ind. For. Rec.*, Ent., v, No, 5, pp, 370, 1.

Brachymeria sp. near **hearseyi** is an internal parasite of the last instar larva of *Calopepla leayana* (Chrysomelidae).

Life-history: The active larva of *Calopepla leayana* carries the moulted skins of previous instars together with a brush of filaments of excrement which are waived over the abdomen when the larva is disturbed. This device appears to be sufficient to protect its owner from parasitism. Before pupation the mature larva sheds the appendage of moults and excrement, and attaches itself ventrally to a leaf by means of a gummy exudation, which makes the thoracic and anterior abdominal segments immobile. Slight movements of the apex of the abdomen are possible but are insufficient to shake off a female chalcid. The parasite oviposits on the dorsal surface of the thorax of the *Calopepla* larva and spends as much as three minutes in the process. She also feeds at punctures which are produced by rapid stabs.

Only one *Brachymeria* larva matures in each host which pupates in a normal manner but turns black eventually. The normal pupal period of *Calopepla* is 7 days (in September). The parasite pupates inside the pupal shell of the beetle and the fly emerges after a life-cycle of 13 to 15 days in September and 17 to 19 days in October.

In the region of Dehra Dun parasitism is rare in July but begins in the first half of August and four generations of the chalcid may occur before the host begins to hibernate (October). The life of the adult chalcid is 7–15 days in September, 30–40

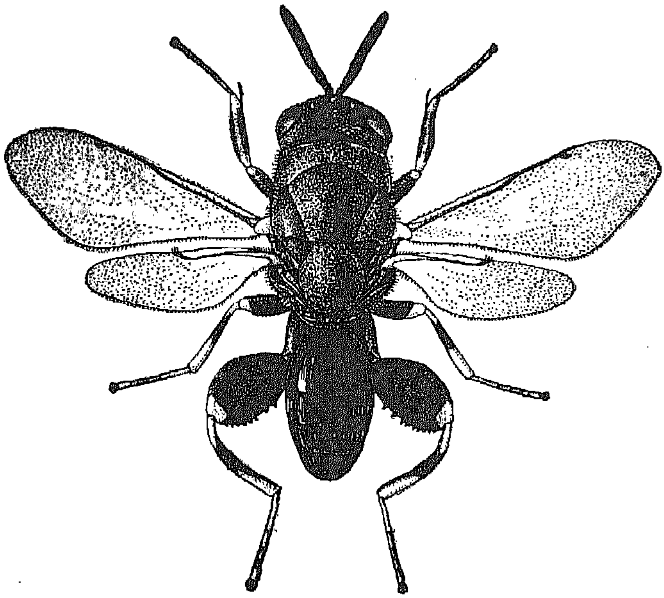

Fig. 139. Brachymeria tachardiae, male, 3 mm.

days in October-November and is prolonged throughout the cold weather and (unless there is an alternative host) the hot weather is also passed in the adult stage. A female may parasitise 10 beetles, and the parasitism-percentage reaches 50.

In Burma the life-cycle is 18-20 days in June-September while the host requires 50 days. There are probably 5 to 6 generations a year.

P. F. Garthwaite, 1939, *Ind. For. Rec.*, Ent., v, No. 2, pp. 252-257.

B. tachardiae, length 2·2 to 3·5 mm., develops in the pupa of several species of moths including *Earias insulana* (Noctuidae) and *Hypsipyla robusta* (Pyralidae), also of *Eublemma amabilis* (Noctuidae) and *Holoocera pulverea* (Tineidae) which are predaceous on the lac insect, *Laccifer lacca* (Coccidae). The life-cycle in the hot weather is between one and two weeks and there are five generations in the year. The egg is laid on the full grown caterpillar on which the parasite feeds externally at first until it pupates and then continues its development as an endoparasite of the pupa. The wasp emerges from the pupa of the host by a circular hole. The wasp is long-lived and may survive for three months through the cold weather. *B. tachardiae* is not of great importance as a factor in the natural control of the predaceous caterpillars damaging lac. [fig. 139].

Dirhinus excavatus on *Sturmia inconspicuella* (Tachinidae) and *Phanerotoma hendecasisella* (Braconidae) parasitic on *Hapalia*

machaeralis (Pyralidae) One adult emerges from each host. The life-cycle is about 16 days. **D. pachycerus** on *Sarcophaga*, *Musca* and *Chrysomyia* (Calliphoridae) and on *Dacus* (Trypetidae).

Stomatoceras ayyari on the larva of *Parasa lepida* (Limacodidae).

Trigoneura ruficaudis and **T. tenuicaudis** (8 mm.) are parasites of sapwood-boring larvae such as *Chrysobothris* (Buprestidae) and *Glenea* (Laminae). The long ovipositor, (which in *tenuicaudis* is half as long again as the abdomen) is used for inserting the egg through thin places in the bark. Pupation takes place in the bark in the pupal chamber of the boring larva.

ELASMIDAE

Mani M S., 1938, *Catalogue of Indian Insects*, Part, 23, Chalcidoidea.
Pruthi H. S and Mani M. S., 1940, *Imp. Counc. Agr. Res., Misc. Bull.* 30, Biological notes on Indian parasitic Chalcidoidea.

The genus **Elasmus** comprises elongate wasps a few millimetres long with the abdomen flat above and carinate below and the wings narrow and the hind coxae broad and flat; they are parasitic on mature caterpillars on which eggs are laid and the larvae feed externally and pupate naked; some are hyperparasites.

Elasmus albomaculatus is parasitic on *Apanteles malevolus* (Braconidae) which is parasitic on the full-grown caterpillars of *Hyblaea puera* (Hyblaeidae). The larva of *A. malevolus* is apparently attacked when nearly full grown and always before it makes its cocoon. The hyperparasite transforms in the cocoon of its host taking 12 to 23 days to emerge as adult.

E. brevicornis on the larvae of *Hapalia machaeralis*, *Psara stultalis* and *Sylepta derogata* (Pyralidae) and of *Hyblaea puera* (Hyblaeidae). The eggs are laid in twos and threes on the setae of the caterpillar. In the case of a caterpillar in the prepupal or hibernating condition the female *brevicornis* remains closely in attendance on the eggs until they hatch. The incubation-period is 24 to 48 hours. The larvae on hatching distribute themselves slowly over the body of the caterpillar and feed externally. As many as 12 *Elasmus* larvae have been observed feeding and successfully maturing on one caterpillar of *Hapalia machaeralis*. The feeding period lasts 3–6 days after which the full-fed parasite withdraws a short distance from the host and voids a black pellet of excrement. The prepupal period may last 2 days. The naked pupa is formed near or attached to the body of the host. The pupal period is 3–12 days giving a life-cycle of 6–22 days. The life-history in Burma and a figure of the adult are given by Garthwaite P. M. and Desai M. H., 1939, *Ind. For. Rec.*, Ent. v, 4, pp. 334, 335. fig. 5. [fig. 140]. Beeson and Chatterjee S. N., 1939, *tit. cit.*, v, 5, p. 375. It is also a hyperparasite, completing its development in the cocoon of *Apanteles machaeralis* and *Phanerotoma hendecasisella* (Braconidae); nine *Elasmus* may

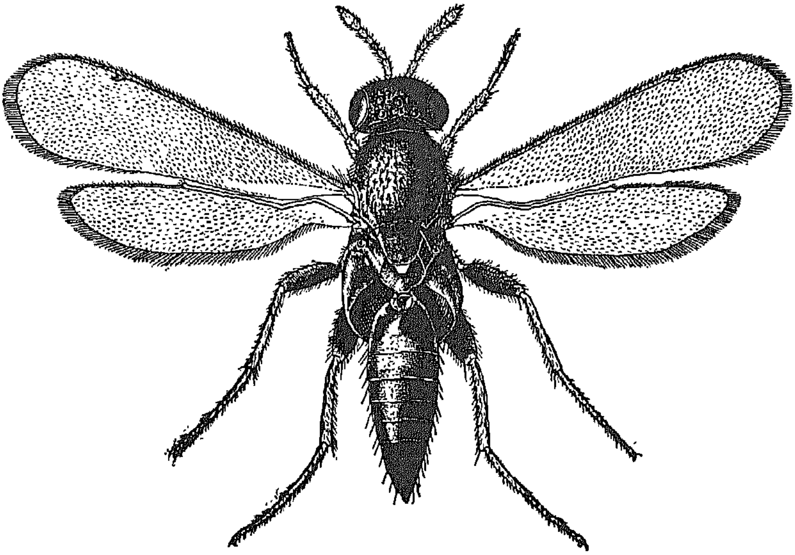

Fig. 140. Elasmus brevicornis, natural size 3 mm.

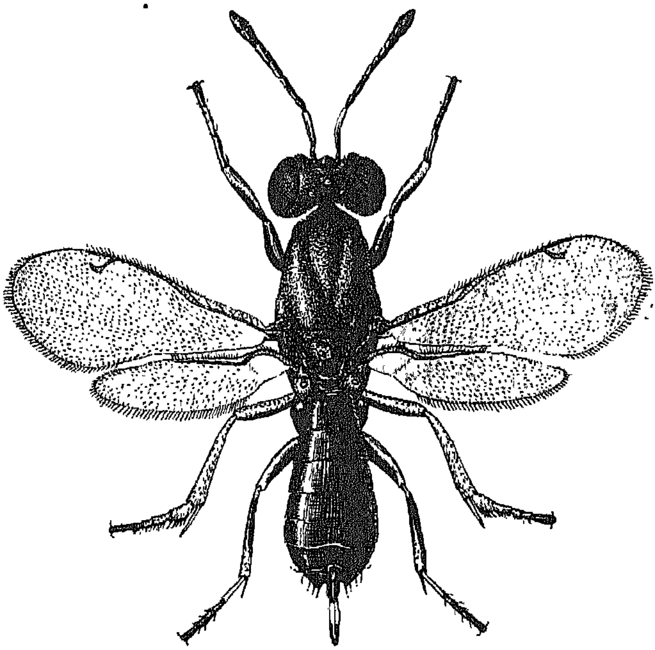

Fig. 141. Eupelmus tachardiae, male, 3 mm.

develop in one *Apanteles* cocoon and the flies all emerge through one hole on the same day.

E. ceylonicus on the bagworm, *Psyche albipes* (Psychidae). **E. claripennis** is black with greenish or violet reflections, abdomen brown, legs yellow; the female, 3 mm., has a simple clubbed antenna and the male, 2 mm., has 2 additional long branches from the middle of the antenna. This species is an ectoparasite of the larva of the lac predator, *Eublemma amabilis* (Noctuidae). Eggs are laid on or near the host larva. The life-cycle is 13 days with a pupal period of 7 days in October. The adults are long lived during the cold weather. It is of minor importance as an agent in the control of the lac predator. India to Malaya. **E. hyblaeae,** black with a brassy green sheen, tibiae and tarsi pale yellow, 1·7 mm., on the 2nd instar larva of *Hyblaea puera* (Hyblaeidae) and the larva of *Noorda moringae* (Pyralidae). **E. indicus** on *Margaronia indica*, *Sylepta derogata* (Pyralidae) and possibly on *Eublemma amabilis* (Noctuidae). **E. johnstoni** is a hyperparasite attacking the parasites of teak defoliators, *Apanteles importunus*, *A. machaeralis*, and *A. malevolus* (Braconidae); up to 4 *Elasmus* adults emerge from the cocoon of the *Apanteles* larva 1 to 2 weeks after formation, but may hibernate in it for 3 months. It is also a parasite of cotton-bollworms, *Earias insulana* and *Platyedra gossypiella* in India and Africa. **E. nephantidis** on *Nephantis serinopa*. Its life-history is described by Y. R. Rao and M. C. Cherian in *Yearbook Dept. Agr., Madras*, 1926–27, pp. 39–50. It has been used for the biological control of the coconut palm defoliator in Madras.

ENCYRTIDAE

Mani M. S., 1938, *Catalogue of Indian Insects*, Part 23, Chalcidoidea.
Pruthi H. S. and Mani M. S., 1940, *Imp. Counc. Agr. Res., Misc. Bull.*, 30, Biological notes on Indian parasitic Chalcidoidea.

Each of the following species is parasitic on the host or hosts recorded for it.

Anastatus colemani in the eggs of *Tessarotoma javanica* and *Degonetus serratus* (Pentatomidae).

Anicetus ceylonenis on *Ceroplastodes*, *Pulvinaria* and *Vinsonia stellifera* (Coccidae).

Compierella bifasciata, a cosmopolitan parasite of *Aspidiotus* spp. and other Coccidae.

Erencyrtus dewitzi, 0·8–1·4 mm. is a primary parasite of the lac insect, *Laccifer lacca*, and also of *Metatachardia conchiferata* (Coccidae).

Eucomys lecaniorum and **E. rufescens** are parasites of *Saissetia hemisphaerica* and *S. nigra* (Coccidae).

Eupelmus tachardiae, 1·3–3·3 mm., [fig. 141] is an enemy of the lac insect, being parasitic on *Laccifer lacca* itself and hyperparasitic on the beneficial species *Microbracon greeni* and *Apanteles tachardiae* (Braconidae); it is also a parasite of *Machaerota*

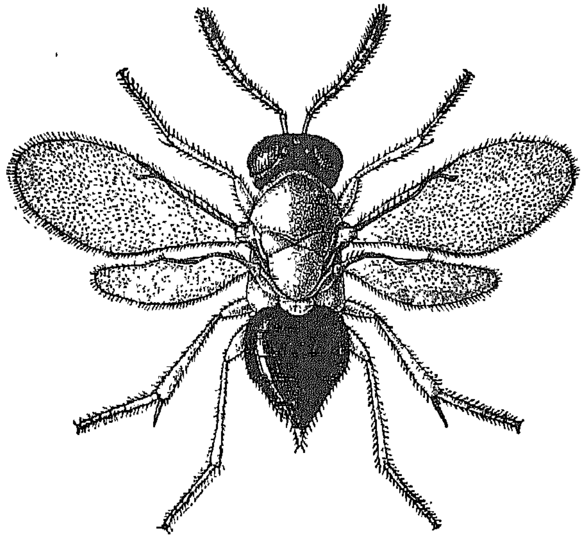

Fig. 142. Tachardiaephagus tachardiae, female.

planitiae (Cercopidae) and of *Laccifer albizziae* in Ceylon. Like many European *Eupelmus* it probably has several hosts and may not be specially connected with lac insects. Its life-cycle in the cold weather lasts for two months, in January for 50 days, in February 44 days, in June 16 days, in July 19 days. The wasp may live through the cold weather for 6 to 9 weeks. *Brasema annulicaudis* is a synonym. *Current Science*, 1935, pp. 37-39, Literature.

Homalotylus flaminius, a widespread species, parasitises the larvae and pupae of Coccinellidae (*Adonia, Brumus, Chilocorus, Novius*, etc.).

Mesocomys orientalis in the eggs of *Trabala vishnou* (Lasiocampidae).

Paralitomastix varicornis, a widely distributed species, is a polyembryonic endoparasite of the nearly mature larva of *Dichomeris eridantis* and other Gelechiidae. 260 parasites may develop in one caterpillar, which is entirely consumed until the distended skin is all that remains; numerous perforations are made by the escaping adults. The highest percentage of parasitism observed in the shisham plantations of the Punjab is 47 in May.

Parechthrodryinus clavicornis, 1-1·6 mm., is a primary parasite of the lac insect.

Proleurocerus fulgoridis, 1·25 mm., in the eggs of *Eurybrachys tomentosa* (Fulgoridae).

Tachardiaephagus tachardiae, 1·2-2·5 mm., [fig. 142] is a primary parasite of the lac insect, *Laccifer lacca*, and apparently does

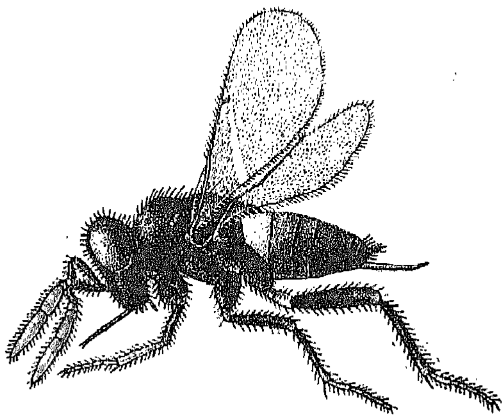

Fig. 143. Aphelinus mali, female, 0·5 mm.

not attack any of the predators or other parasites of lac. It is generally abundant and has 5 generations in the year, emerging in every month, but mostly just after the lac crop is cut. Also on *Laccifer albizziae*, *L. javanus* (Coccidae). *Lissencyrtus troupi*, *T. thoracicus* and *T. somervilli* are synonyms.

EULOPHIDAE

THE family EULOPHIDAE comprises many species with a wide range of habits including parasitism in the eggs of beetles, bugs and cockroaches, larvae of beetles and flies, and scale-insects, as well as caterpillars. Several unnamed species are associated with teak defoliators and their parasites.

Mani M. S., 1938, *Catalogue of Indian Insects*, Part 23, Chalcidoidea, pp. 110, 151.

Pruthi H. S. and Mani M. S., 1940, *Imp. Counc. Agr. Res., Misc. Bull.* 30, Biological notes on Indian parasitic Chalcidoidea.

Aphelinus mali is a parasite of the Woolly Aphis, *Eriosma lanigera*, a pest of apple trees. It has been utilised extensively for the control of the Woolly Aphis in many countries in all continents to which the aphis had been introduced. The parasite was introduced and established in Kashmir and the Kulu valley and Simla Hills, Punjab, in 1937 and further distribution in north and south India is in progress. The female deposits one or more eggs in the abdomen of an aphis but only one parasite reaches maturity. The life-cycle takes about 10–15 days and there are about 14 generations a year.

Cassidocida aspidomorphae, in larvae ot *Aspidomorpha miliaris* (Chrysomelidae).

Coccophagus tschirchii, 1–1·7 mm., a yellow species with a

black abdomen, is a parasite of *Laccifer lacca* and has 5 generations a year. It is very abundant just after the lac crop matures.

Euplectromorpha viridiceps, 1·5–2·5 mm., a parasite of *Artona catoxantha*, *Dasychira* spp. (Lymantriidae).

Euplectrus euplexiae, on *Perigea capensis* and *Spodoptera mauritia* (Noctuidae). **E. ceylonensis** on caterpillars of *Euproctis fraterna* (Lymantriidae).

Euplectrus sp.

This undescribed species is an ectoparasite of the larva of *Plecoptera reflexa* (Noctuidae). Male, 1·3 mm., female 1·6 mm., head and thorax black, abdomen petiolate, yellow with a dark transverse band near the middle, legs pale yellow, wings colourless.

Life-history: Pairing takes place when the couple are a few hours old and is momentary. The female attacks caterpillars in the youngest instar, leaping swiftly, and temporarily paralysing the host with a stab of the ovipositor. The body-fluid of the caterpillar exudes at the wound and an egg is deposited on it and cemented in position by the congealed fluid. Up to 8 eggs may be laid on the back or sides of one caterpillar but 2 to 3 grubs is the normal infestation; usually not more than 6 parasites can mature on one second instar caterpillar. The host may be killed by one parasite.

The egg is depressed ovoid, white, 0·2 mm. long, darkening in 24 hours. One female may lay 50 eggs in the course of 10 days with a maximum of 17 eggs in one day and may parasitise 25 hosts. The larva in its first and successive instars feeds externally on the host at one spot and the moulted skins accumulate behind it. The fourth stage larva is 2×1 mm., plump-bodied with the anterior end broadly convex and the 4 posterior segments tapering in a telescopic "tail" which is capable of considerable elongation. The host continues to feed actively while the parasites are maturing but eventually succumbs and is sucked dry. The parasitic larvae leave the place of attachment and form their cocoons conjointly. The cocoon or cell is composed of a secretion from the Malipighian tubes passed out at the end of the posterior tail and picked up by spinnerets on the body and drawn into coarse thick threads in an open network.

The larval period lasts 3–5 days in the warmer seasons; there is a prepupal stage of 1 day and the pupal period lasts 3 to 5 days in May–July and 4–6 days in August, September. The total life-cycle is thus 7–11 days; the number of generations must be very high. The adult *Euplectrus* lives only a few days in the hot weather but for 100 days in extreme cold weather. The female feeds on the body-fluid of the host at punctures made by the ovipositor. The male needs water daily. The percentage-parasitism of *P. reflexa* in shisham plantations is moderately high but not exceeding 40 percent.

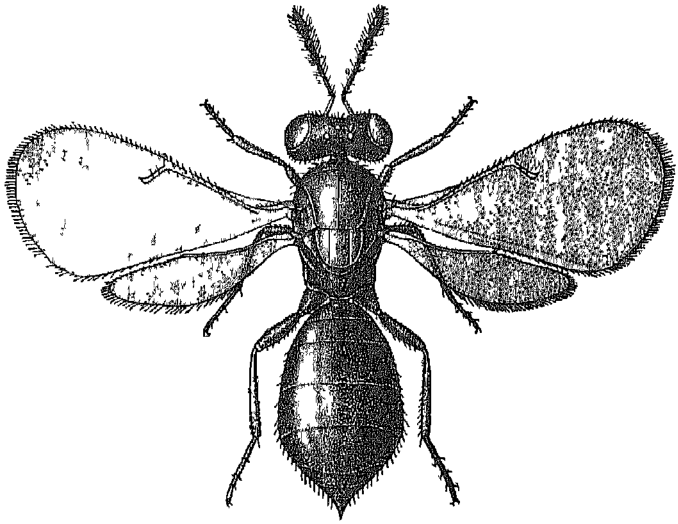

Fig. 144. Tetrastichus spirabilis, female, 1·5 mm

Marietta javensis, 0 5–0·9 mm , in *Laccifer lacca* chiefly in the male cells. It is also a hyperparasite of female cells, and of chalcidoid parasites of *Aspidiotus orientalis* (Coccidae).

Neoplectrus maculatus, 1·5 mm., on *Artona catoxantha, Natada nararia* (Limacodidae)

Pareuderus torymoides in the eggs of *Alcides leeuweni* and *Lixus truncatulus* (Curculionidae), the life history is given by T. Ahmad, 1939, *Ind Journ Agr Sci* , IX, pl. XXVIII, figs. 1 6, pp. 618–620.

Syntomosphyrum obscuriceps, 1 mm , a secondary parasite through puparia of Tachinidae and pupae of Braconidae.

Tetrastichus ayyari on the pupae of various Pyralidae , in the laboratory it has been bred in the pupae of several species of Pyralidae and Noctuidae and also of *Hyblaea puera.* The total life cycle from egg to the emergence of the adult is 14–16 days.

Cherian M C and Subramaniam C K , 1940, *Ind Journ Ent* , pp 75-77, figs 1-4, Tetrastichus ayyari Rohw a pupal parasite of some moth borers in south India

Tetrastichus colemani on larvae of *Aspidomorpha miliaris* (Chrysomelidae).

Tetrastichus purpureus, 1·2–1 8 mm , black with purplish and greenish reflection, legs and the base of the abdomen yellow, is the commonest of the chalcidoid parasites of the lac insect throughout India, and is a primary parasite of *Aspidiotus orientalis* (Coccidae), a scale occurring on host trees of lac It is also hyperparasitic on some other lac parasites (*Coccophagus tschirchii* and *Tachardiaephagus tachardiae*), but is of no economic importance in the latter respect as it is primarily a lac parasite. It

emerges from lac in every month of the year and has at least 6 generations but is most abundant at crop-maturity.

Tetrastichus ? rapi in the caterpillar of *Cremastus hapaliae* (Braconidae). **T. spirabilis**, 1·5 mm., in the caterpillar of *Hysipyla robusta* (Pyralidae) while boring in the shoots of *Cedrela toona*. [fig. 144]. **Tetrastichus** sp. in the pupa of *Hapalia machaeralis*. A maximum of 70 parasites may mature in one pupa.

Trichospilus pupivora, orange-yellow with the abdomen of the female brownish-black, 1–2 mm., in the pupae of various moths including *Acontia graellsi*, *Cnaphalocrocis medinalis*, *Ergolis merione*, *Hapalia machaeralis*, *Nephantis serinopa*, *Prodenia litura*, *Thosea cervina*, *Spodoptera mauritia*, *Sylepta derogata*, *Tirachola plagiata*.

Its chief host is the black-headed palm-caterpillar, *Nephantis serinopa* (Xyloryctidae). In Ceylon and Madras it has been multiplied and liberated in large numbers since 1935 for the control of this pest.

Life-history: The adults live about a week. Eggs are laid in very large numbers on the host pupae and hatch in 24 hours. The feeding-period of the parasitic larva is 5 to 7 days, and pupation takes place within the shell of the pupa of the host. Over 100 parasites may mature inside a single pupa. The pupal stage of *pupivora* lasts 8 to 10 days. The whole life-cycle is completed in 16 to 17 days under favourable conditions in south India, but the period extends to 20 days during wet weather in June and is reduced to about 15 days during the dry hot weather of March–April. In all 22 generations may be completed in a year. In Ceylon the life-cycle lasts from 15–23 days.

LITERATURE:

Anantanarayanan K.P., 1934, *Bull. Ent. Res.*, 25, pp. 55-61, On the bionomics of the Eulophid (Trichospilus pupivora Ferr.).
Hutson J.C., 1937, *Adm. Rep. Dept. Agr.*, Ceylon for 1936.
Backhouse J.R.C., 1939, *Trop. Agr.*, XCII, pp. 163, 164.
Garthwaite P.F. and Desai M. H., 1939, *Ind. For. Rec.*, Ent., v, 4, p. 351.

EUMENIDAE

SOLITARY Wasps or Mason Wasps or Potter Wasps are the names used for EUMENIDAE but these are sometimes applied also to some of the Sphecoidea. They are stinging predators, paralysing caterpillars and storing them in cells of mud to serve as food for their larvae. The brood of one eumenid wasp accounts for very many caterpillars but the wasp-population as a whole is rarely large enough to affect appreciably the abundance of a pest which is its prey.

Dutt G.R., 1912, *Mem. Dept. Agr. Ind.*, IV, 4, pp. 229-242, figs. 14, pl. XIII.
Hingston R.W.G., 1926, *Journ. Bomb. Nat. Hist. Soc.*, XXXI, pp. 241-247, 754-761, 890-896. figs., The mason wasp. — 1927, *tit. cit.*, XXXII, pp. 98-110, 246-252, figs., The potter wasp.

Eumenes conica, E. dimidiatipennis and **E. esuriens.** The female mason wasp builds a cluster of several globular mud-cells

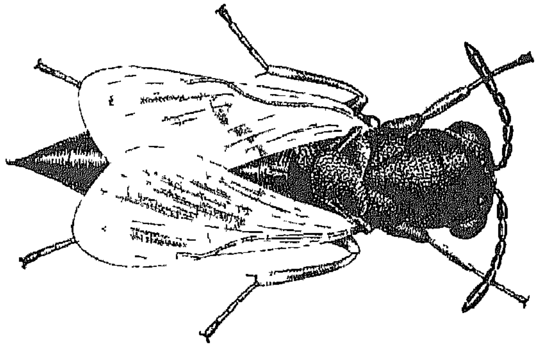

Fig. 145. Eurytoma curculionum

each about an inch in diameter, and each containing 3 to 9 (usually 5) paralysed noctuid caterpillars on which one egg is deposited. A detailed study of the psychology and life-history of *E. conica*, the Mason Wasp, is given by Hingston, 1926, see also Dutt, 1912.

Rhynchium brunneum and **R. nitidulum**, The Potter Wasps, build a group of narrow barrel shaped mud-cells coated with a mucilage of gum and filled with paralysed caterpillars, over 40 of which may be supplied for the food of one wasp larva. The life-cycle is completed in 23-24 days. A detailed study of *R. nitidulum* has been made by Hingston, 1927; see also Dutt, 1912.

EURYTOMIDAE

Mani M. S., 1938. *Catalogue of Indian Insects*, Part 23, Chalcidoidea
Pruthi H S and Mani M S. 1940, *Imp Counc. Agr. Rec*, *Misc Bull* 30, Biological notes on Indian parasitic Chalcidoidea

Eurytoma albotibialis parasitises the larva of *Perisierola nephantidis* (Bethylidae). **E. braconidis** in *Apanteles machaeralis* (Braconidae). **E. curculionum**, a palaearctic species, in larvae of *Lixus truncatulus* and other weevils. [fig. 145]. **E. monemae** in *Parasa lepida* and *Thosea* (Limacodidae).

E. palidiscapus, 1·5–3·8 mm., is an endoparasite of the pupa of *Holcocera pulverea* (Noctuidae) and a casual hyperparasite of the lac friends, *Microbracon greeni* and *Apanteles tachardiae* (Braconidae). **E. pigra** in the larva of *Alcides bubo* (Curculionidae). **E. setitibia** in nymphs of *Trioza fletcheri* (Psyllidae). **E. xylotrechi** in *Xylotrechus quadripes* and *Chlorophorus annularis* (Cerambycidae).

EVANIIDAE

Mani M, S.. 1939, *Catalogue Ind. Ins*, Part 24—Evaniidae.

PARASITISM in the family of EVANIIDAE affects several orders. In the genus **Evania** are parasites of the egg-capsules of cock-

roaches (Blattidae). **Gasteruption** is parasitic on various genera of solitary bees and wasps (Vespidae and Sphecoidea).

Pristaulacus beesoni, a black wasp (less than $\frac{1}{2}$ an inch with clear wings having one black marginal spot), is a parasite of small longicorns, particularly *Xylotrechus smei* (Cerambycidae) and of *Chrysobothris beesoni* (Buprestidae). The life-cycle is apparently annual in north India with emergence from May to September. **Pristaulacus nigripes** is a parasite of the larva of *Xylotrechus quadripes.*

FORMICIDAE

COMPRISING over 6,000 different forms (species, subspecies and varieties) the FORMICIDAE are far and away the largest and most successful group of social insects; about $\frac{3}{4}$ rs of the species occur in the tropics. No other social group has attained the dominance of the ants in the insect fauna of the world.

Castes of ants: Polymorphism is very complex. The *male* ant is an extraordinarily conservative and stable organism, although known to be dimorphic in a few species; the female ant shows a wide range of variation including 21 different forms, some of which are pathological or otherwise atypical, or are excess and defect developments such as giants and dwarfs. There are really only 3 typical forms or castes of the female, viz., *queen, soldier* and *worker,* each of which is the basis of development of atypical and pathological types.

Ant colony: At certain seasons the winged females and winged males swarm and fly away from their parental nest. After pairing the males soon die but the female seeks a site for founding a new colony or formicary. She sheds her 2 pairs of wings and the voluminous vibratory muscles disintegrate and the products pass into the blood plasma for the nourishment of the ovarian eggs and the lengthening of the life of the female during the early stages of the rearing of the brood. The eggs are laid in the cavity of the nest (in the soil usually); the freely exposed larvae are directly fed by the female; no cells are formed and they pupate each in a cocoon of silk which it has spun. (Some genera, e.g., *Crematogaster* pupate naked). The first caste to emerge from these cocoons are wingless workers who at once take over the care of the larvae and of the queen who confines her activities thereafter to egg-laying. She may live 10–15 years. In some species the mated females return to the family nest and all live together harmoniously and contribute to the population of the colony. When it becomes too crowded one or more queens may migrate accompained by a clan of workers. The population of a flourishing colony of *Formica* it estimated at between 100,000 and 500,000 individuals.

The feeding-habits of ants are varied and complex; there are hunting, pastoral, agricultural and slave-making types.

All the most primitive genera are carnivorous, hunting chiefly insects. The Ponerinae are almost exclusively insectivorous, some species specialising in particular forms of insect diet, for example, caterpillars may form ⅘s of the total food; the economic value of this group of predators in the tropics cannot be over-estimated. Other tribes live mainly on saccharine matter obtained from plants or as honey-dew produced by Aphidae and other gregarious sap-sucking Homoptera. Those species which protect and 'domesticate' herds of aphids and scale-insects are ranked as pastoral. The so called harvesting ants (Myrmecinae) collect plant-seeds, storing the edible parts in granaries and throwing away the husks. Truly agricultural ants raise crops of fungi in special gardens which are practically monocultures, all weeds and undesirable forms being eliminated.

"Nests or formicaries present an almost bewildering variety of architecture. Not only has every species its own plan of construction but this plan may be modified in various ways in adaptation to special local conditions". (Imms). Nest-sites occur in the soil, in decayed vegetable matter and on living parts of herbaceous plants and trees. Portions of stems or leaves may be roofed in or woven together with silk by the weaver ants (*Oecophylla*, *Polyrhachis*). Plant pulp or carton is used by many genera for the construction of nests and shelters.

There is a very extensive literature on the social economy and importance of Formicidae as units in a biocoenosis, which is essential for the serious worker. Very few original investigations have been made of these aspects of the ant fauna of the Indian region; here is a profitable field for research which should yield results of practical value in biological control of forest insect pests. Relatively few species are injurious pests and are so because they protect harmful scale-insects, or attack young plants, or scavenge in man's dwellings.

Enemies of Formicidae: The most dangerous arthropod enemies of ants are other ants of the same or of different species. A particularly agressive species of ant may exert a great influence on local ant-fauna; the accidental introduction by man of the Argentine Ant, *Iridomyrmex humilis*, to various parts of North America has been followed by the reduction or total disappearance of the indigenous species of ants. In Madeira, for instance, *I. humilis* has almost eliminated *Pheidole megacephala* which was previously the house ant of that island. *P. megacephala*, on the other hand, has exterminated the indigenous species in parts of the Pacific islands.

For the rest ants are relatively immune from the attacks of most predaceous arthropods except some spiders, tiger beetles and Carabidae, ant-lion larvae, Reduviidae and fossorial wasps. Frogs, toads, and blind-snakes (Typhlops) feed on ants; among birds woodpeckers and sapsuckers largely eat ants. Various insectivorous

and omnivorous mammals such as bears, moles, shrews and monkeys feed occasionally on ants; the pangolin or scaly anteater (Manidae) is specialised for a diet that consists almost exclusively of ants.

LITERATURE ON FORMICIDAE:

Bingham C. T., 1903, *Fauna Brit. Ind.*, Hymenoptera, II, Ants and Cuckoo-wasps, pp. 414, figs. 145.

Dutt G. R., 1912, *Mem. Dept. Agr. Ind.*, pp. 246-267, figs. 17-22, pl. XIV, Life-histories of Indian insects, IV.

Hingston R. W. G., 1920, *A naturalist in Himalaya.*

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— 1928, *Problems of instinct and intelligence.*

Mukerjee D., 1930, *Journ. Bomb. Nat. Hist. Soc.*, XXXIV, pp. 149-163, Report on a collection of ants in the Indian Museum, Calcutta.

— 1934, *Ind. For. Rec.*, XX, V. Entomological investigations on the spike disease of sandal, (22), Formicidae.

Negi P. S. Misra M. P. and Gupta S. N., 1930, *Journ. Bomb. Nat. Hist. Soc.*, pp. 182-188, Ants and the lac insect.

Acantholepis frauenfeldi sericea feeds on dead insects, etc. and also attacks living caterpillars, e.g., *Plecoptera reflexa.*

A. pulchella attends Psyllidae on various trees.

Camponotus compressus, the large Indian Black Ant, is one the commonest species. "The most favoured site for the selection of the formicary is at the base of a large tree. There the ants dig themselves into the soil and heap the ejected debris into a mound about the nests. At the summit of the pile is the aperture, which, if well chosen, leads into a natural fissure in the trunk." (Hingston). They also use natural cavities and hollows in rocky ground, walls, tree trunks, etc.; they do not make arboreal nests or byres. The food-supply is the excretion of sapsucking insects, Aphidae, Coccidae, Cercopidae and some Lycaenid caterpillars. They collect dead insects and also attack and overcome live caterpillars, e.g. *Plecoptera reflexa.* The workers visit lac while it is on the tree to remove the honeydew excreted by the lac insect. This does no harm to lac, on the contrary is sometimes beneficial since the honeydew becoming coated with dust in dry weather may block the respiratory system of the lac insect.

The ants may break the brachial wax filaments, but apparently without serious consequences. The young caterpillars of the predaceous moths are killed by the ant if captured when attempting to penetrate the lac cells. Other Homoptera producing honeydew are also attended, e.g., *Arytaina punctipennis*, *Euphalerus vittatus*, *Phylloplecta* sp., *Psylla* sp. (Psyllidae).

Ayyar P. N. K., 1937, *Journ. Bomb. Nat. Hist. Soc.*, XXXIX, pp. 750-754, Marriage flight and colony founding of the common black ant, Camponotus (Tanaemyrmex) compressus.

Hingston R. W. G., 1920, 1925 and 1928, *op. cit. supra.*

Camponotus mitis, C. paria and **C. sericeus** occasionally visit lac on the tree. They attend Psyllidae (*Arytaina* sp., *Paurocephala* sp.) and also attack living caterpillars.

The myrmecine genus **Crematogaster** includes predaceous

cocktailed ants making shelters of carton, etc. on or in parts of plants. "When excited or moving quickly, the ants turn their broad subcordate abdomen over their backs, the feat being more easily performed owing to the fact that in this genus the apex of the pedicel is fixed to the upper margin of the base of the abdomen and the upper surface of the abdomen itself is more or less flat, the lower surface convex". (Bingham). The life-history of one species **auberti** is described by Hingston R. W. G., 1925, *Journ. Bomb. Nat. Hist. Soc.*, XXX, pp. 541--550, pl., The Cremastogaster ant. And of another species **dohrni artifex** by Ayyar P. N. K., 1937, *tit cit.*, XXXIX, pp. 291–308, 4 pls. The latter species constructs a globular nest of carton as big as a football attached to the branch of a tree and housing a colony of 70,000–100,000 individuals. Foraging parties are sent out daily for provisions which consist of termites, hairless caterpillars and grubs, and small defenceless insects as well as of sweet fluids from plant saps and nectar.

Diacamma vagans makes nests in the soil at the bases of trees ; it attacks and carries away large caterpillars of *Hyblaea puera* (Hyblaeidae).

Dorylus labiatus is partly carnivorus attacking other ants, and partly herbivorus, feeding on tubers and roots.

D. orientalis, The Root-eating Ant. The workers, 2·5–5 mm., are yellowish to reddish-brown, with large rectangular heads, deeply furrowed in the middle; the pedicel is one-jointed and the abdomen is elongate and flattened above, so that there is no distinct waist; the large winged males resemble wasps somewhat and come to light at night. The nest is underground at a considerable depth. These driver ants work through the soil, feeding on the rootlets of plants and may be found congregated in large numbers near the roots of a dying plant. The species is occasionally a pest in gardens (particularly of vegetables) and in seed-beds and nurseries. The soft parts of the roots and the root-collar of seedling trees may be eaten. Plants with bulbous or tuberous roots are hollowed out. *D. orientalis* appears to be entirely herbivorous in its food.

Hutson J. C., 1933, *Trop. Agr.*, LXXX, pp. 276-279, The root eating ant.
— 1936, *tit. cit.*, LXXXVII, pp. 293-295, The root eating ant, Dorylus orientalis Westw.

Iridiomyrmex anceps frequents lac for the honeydew.

Lobopelta kitteli attacks the caterpillars of *Xyleutes ceramica* (Cossidae). **L. ocellifera** attacks termites.

Messor barbatus instabilis feeds on dead insects and also attacks living caterpillars, e. g., *Plecoptera reflexa*.

Meronoplus bicolor frequents lac for the honeydew.

Monomorium destructor invades houses and makes its nest in the walls or flooring; the ants feed on all sorts of refuse and food-substances but particularly on meat and sweets. They

damage fabrics and electrical wire-insulating materials.

Monomorium glycephilum frequents lac for the honeydew. **M. gracillimum** is another minute species that is a general pest in houses, particularly because it gets into bedding and clothing and has a very irritating bite.

Myrmicaria brunnea. Where the large subterranean nests of this species occur in abundance considerable damage to young trees may result. The ants bite away the tips of the buds and assemble in large numbers to feed upon the plant-juices which exude from the wounds. They also eat the surface-tissue of the young shoots and make holes in the younger leaves. It is a pest in citrus groves (Clausen).

Myrmecocystus setipes feeds generally on dead insects: it also attacks and overcomes living caterpillars, e.g., *Plecoptera reflexa*.

Oecophylla smaragdina. The Red Tree Ant, is one of the ants living in colonial nests in the foliage of trees. The nest is constructed by drawing together into a bunch the leaves of several adjacent shoots. While some of the worker ants hold the leaves in place with their mandibles and legs, other workers stick the leaves together with silk which is produced by the ant larvae carried in the jaws of the workers and applied to the spots where the adhesive is required. In addition to the main nest there are usually several subsidiary chambers containing stored food-material or living scale-insects, which the ants protect and cultivate for the sake of their secretions. The webbed up leaves and shoots die back but the injury to the tree is negligible. The presence of the ant-colonies is a nuisance to workers in the forest, particularly in felling areas, owing to the painfulness of the bite and their readiness to attack.

In China and Java this ant is valued by fruit-cultivators for the benefits conferred by its presence in destroying the insect pests of the groves and plantations. The nests are collected during the cold season while the ants are fairly inactive and are transported to areas which it is desired to protect and are placed in the trees. The larger branches and trunks are banded to prevent the escape of the ants and to confine their feeding to particular trees. In the spring the adult ants emerge from the nest and construct a new one from fresh foliage. Split bamboos are slung from tree to tree to permit of more extended foraging. If sufficient insect food-material is not available early in the season to maintain the colony they are regularly fed by the cultivators (Clausen).

Beeson, 1930, *Ind. For.*, LVI, pp. 137-138, Nest of the red ant

Hingston R.W.G., 1923, *Journ. Bomb. Nat. Hist. Soc.*, XXXIX, pp. 362-372, 2 pls., fig., The red ant.

— 1928, *Problems of instinct and intelligence.*

Prater S.N., 1936, *Ind. State Rly. Mag.*, IX, pp. 841-844, Red ants.

Phidole indica lives in large communities and nests on the ground and sends out armies to bring dead insects to the nests.

Polyrhacis armata and **P. dives** are weaver ants, spinning together leaves of plants by means of silk produced by the larvae.

Polyrhacis simplex makes a nest of earth and debris and silk excavated in the ground at the foot of a tree. This is the primary abode of the colony from which it sends columns into the foliage where they break up in search of plant-lice, membracids, etc. It feeds on dead insects and also attacks living caterpillars, e.g., *Plecoptera reflexa*. Small arboreal nests on twigs or leaves are also made of vegetable fragments glued together and sometimes lined with silk. These are used as "byres" but also for temporary housing of the colony.

Hingston R.W.G., 1928, *Problems of instinct and intelligence*, pp. 111, 141, 160, 173.

Prenolepis longicornis, a small black ant, usually frequents bungalows.

Solenopsis geminata, the Brown Fire Ant, lives in nests in the soil and is occasionally injurious to seedlings, biting holes in the leaves and buds. The subspecies **geminata rufa** nests under trees, or in the sides of banks, or at the bases of the outer walls of houses. In sandy soil the nest is marked by quantities of fine particles of soil brought out and spread in low heaps on the surface of the ground in the neighbourhood of which are numerous entrance-holes. Its sting is severe. This small red ant is an important enemy of aphids and soft scales, termites, bed bugs and of the larvae, etc. of the moths predaceous on the lac insect, and practical use can sometimes be made of its activities. The nests are dug up as intact as possible and removed in baskets or kerosene tins and reburied in soil containing termites, the runs and termitaria of which are dug over and broken up to give easy access to the ants. The colonies can be introduced similarly into godowns containing stored scraped lac which is by this means cleared of predaceous caterpillars of *Eublemma amabilis* and *Holcocera pulverea*. This ant also frequents trees bearing lac and removes the honeydew excreted by the lac insects, thus clearing up the encrustation and preventing the blocking of the brachial pores. The living lac insects are not harmed by the ant. During periods of scarcity of insect-food the species may eat away the surface-tissue of young shoots and the lower epidermis of young and mature leaves.

Negi P.S., 1932, *Jour. Bomb. Nat. Hist. Soc.*, XXXVI, pp. 1018-1021, The small red ant Solenopsis geminata subsp. rufa and its usefulness to man.

Tapionoma indicum attends Psyllidae on various trees.

ICHNEUMONIDAE

UNDER the head of ICHNEUMONIDAE are classed parasitic Hymenoptera similar in size, form and habits to the Braconidae and distinguished by morphological characters mentioned on

page 470. It is a very large family of which the Indian representatives have been studied by several taxonomists but have not yet been fully monographed. Its importance in the biological control of forest insect pests parallels that of the Braconidae. The hosts include free living and concealed larvae and pupae of Lepidoptera, wood-boring Coleoptera, parasitic and predaceous Hymenoptera and less frequently some groups of Diptera, Rhynchota and Neuroptera. The modes of oviposition and larval development resemble those found in the Braconidae. viz., egg laid (a) on the host and the larva feeds externally as an ectoparasite, e.g., *Melcha*, or (b) inside the host and the larva is endophagous, pupating within the shelter of the host's cocoon, e.g. *Cremastus*, *Dioctes*, or emerging to spin a separate external cocoon, e.g., *Charops*, *Pristomerus*, *Trophocampa*. Most species are solitary, i.e., one individual matures in one host. Hyperparasitic species are numerous, e.g., *Mesochorus*, *Microtoridea*. The number of generations per annum varies with species from 1 to about 15.

LITERATURE ON ICHNEUMONIDAE:

Beeson and Chatterjee S N., 1935, *Ind. For. Rec.*, Ent., I, No. 8, pp. 151-168, figs. 3, On the biology of the Ichneumonidae.

— 1939, *tit. cit.*, V, No. 5, pp. 357-379, Further notes on the biology of parasites of teak defoliators in India.

Cushman R. A., 1927, *Rec. Ind. Mus.*, XXIX, pp. 241, 247, New Indian Ichneumonidae.

— 1934, *Ind. For. Rec.*, XX, vii, pp. 1-8, fig. 1, New Ichneumonidae from India and China.

— 1937, *tit. cit.*, III, No. 7, pp. 141-147, fig. 1, Four new Indian Ichneumonidae.

Garthwaite P. F. and Desai M. H., 1939, *Ind. For. Rec.*, Ent., V, No. 4, pp. 309-353, figs. 7.

Morley C., 1913, *Fauna Brit. Ind.*, Hymenoptera III, Ichneumonidae, Pimplinae, Tryphoninae, Ophioninae, pp. 531, figs.

Sen A. C., 1930, *Journ. Proc. As. Soc. Beng.*, n. s., XXVI, pp. 317-338, The external morphology of a common Ichneumon fly of India, Xanthopimpla pedator.

Allocamptus sinuatus is parasitic on *Trabala vishnou* (Lasiocampidae).

Anomaloctenus melleus, 10 mm., parasitic on the full grown caterpillar of *Hapalia machaeralis* (Pyralidae). One individual develops in each host, feeding internally for most of its larval period but eventually emerging and feeding externally shortly before pupating in a dark red cocoon, 13 mm. long. The life-cycle is about 28 days in December in Burma and 18 days in May and June in India.

Aphanistes eupterotes, 20 mm., in the caterpillar of *Eupterote geminata*, hibernating in the pupa from October and emerging in March, April in north India.

C. bimarginatus, 14 mm., on the larva of *Lixus truncatulus* (Curculionidae). **C. odinae,** 12 mm., with an ovipositor 16 mm. long, parasitises the larva of *Rhadinomerus fluctiger* (Curculionidae). **C. xanthosoma** on the caterpillar of *Trachylepidia fruti-*

cassiella (Pyralidae).

Campoplegidea deodarae, 9 mm., black with the apex of the abdomen red, is in flight in May, June when the host, *Ectropis deodarae* (Geometridae), which has an annual life-cycle, is in the caterpillar stage. The parasitised caterpillar descends to the ground and pupates in the humus and needle-litter at the beginning of the monsoon. The single parasite remains dormant in the pupa of the host from July until the spring of the following year and emerges as adult in April, May.

Charops erythrogaster, on *Achaea janata* (Noctuidae).

Charops ganges, 10 mm., is a solitary endoparasite of the caterpillar of *Selepa celtis* (Noctuidae), emerging to spin a cocoon with smooth, thick, toughly woven walls, pale brown with the ends capped with black and pre-apical bands of round black spots. The host has 5 or 6 generations a year with one pupating in November–December and yielding moths in March. *C. ganges*, when parasitising this generation, has a long larval period and emerges in January after a cocoon-period of 2 to 3 weeks in November and 3 to 4 weeks in December. Cocoons formed from late larvae in January produce adults in February after 4 weeks.

Cremastus hapaliae, 7 mm., India and Burma, is an internal parasite of the 1st and 2nd instar caterpillars of *Hapalia machaeralis* one individual developing in each host. The cocoon is ashy to light reddish-brown, 7 × 2 mm., and is formed under the shelter of the silk web of the host. In Burma the life-cycle ranges from 16 – 43 days averaging 18 days in June (egg + larva 12, pupa 6) and 30 days in January (egg + larva 17, pupa 13). In India the cocoon-period is about 8 days in April and 10 days in May–June, 9 days in July and 11 days in October. Mating to oviposition takes about 3 days. The female may live for 2 months and parasitise 200 or 300 larvae. The maximum recorded percentage-parasitism is 24. This species appears with the first generation of the host when it is feeding on the new flush of leaves on coppice-shoots and young saplings of teak, and runs through about the same number of generations as does the host.

Beeson and Chatterjee S.N., 1935, *Ind. For. Rec.*, Ent., I, No. 8, p. 156, fig 1. Garthwaite and Desai, 1939, *tit. cit.*, V, No. 4, pp. 326-328.

Cremastus flavo-orbitalis on *Antigastra catalaunalis* (Pyralidae), *Argyroploce illepida*, *A. paragramma* (Eucosmidae), *Chilo simplex*, *Euzophora perticella*, *Leucinodes orbonalis* (Pyralidae).

The adult has a slender testaceous body, 8 mm. long with abbreviated wings and is a solitary internal parasite, mainly of pyralid or eucosmid caterpillars boring shoots or fruits in the Holarctic, Oriental and Pacific regions. In the Hawaiian Islands it has over 30 hosts. It is also a parasite of the European Corn Borer, *Pyrausta nubilalis*, and has been introduced from the Orient into North America for the control of that pest. The egg is 0·5 mm. long. The larva has 3 instars and is about 8 mm.

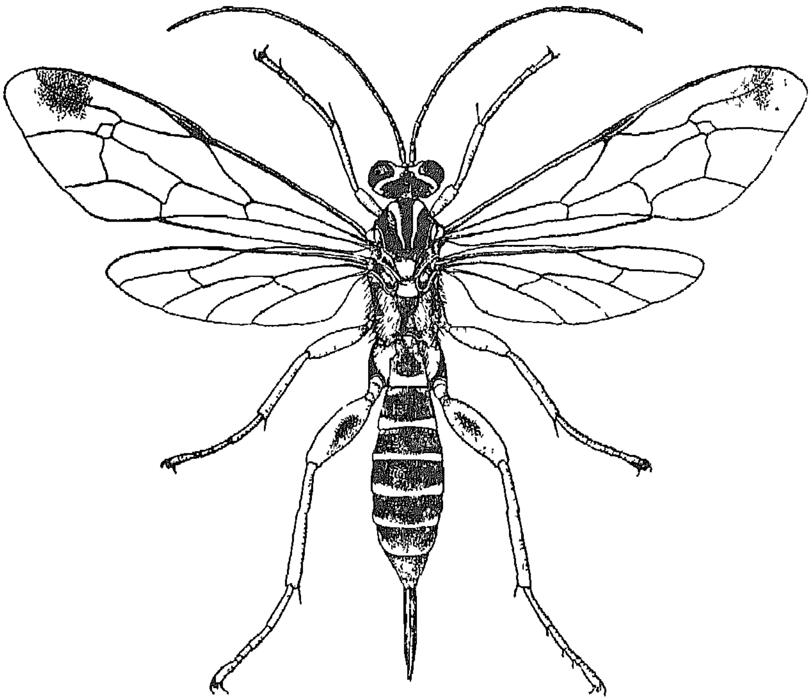


Fig. 146. Echthromorpha notulatoria, natural size 14 mm.

long when full grown. The cocoon is 7 to 10 mm. long varying in colour from greyish-tan to dark brown with a lighter band round the middle and enclosed in a loose, finely woven, silk sheath. At an average temperature of 80° F. and a relative humidity of 70 percent the egg-stage lasts $3\frac{1}{2}$ days, the larval stage 8 days and the cocoon-stage 10 days.

Cremastus noxiosus nigrescens on *Diacrisia obliqua* (Arctiidae).

Dioctes argenteopilosa on *Glyphodes conclusalis, Hapalia machaeralis Lygropia quaternalis, Pilocrocis milvinalis, Sylepta balteata* (Pyralidae), *Hypocala moorei, Laphygma exigua, Prodenia litura* (Noctuidae); India and Burma.

Caterpillars of *Hapalia machaeralis* are parasitised in the 2nd and 3rd instars and one parasite develops in each host. It emerges to spin an elongate dark brown cocoon, measuring about 8 × 3 mm., abruptly rounded and of equal breadth at both ends and situated under the shelter of the *machaeralis* web. In India in July to September the larval period is 11 or 12 days and the cocoon-period 7 or 8 days. The total life-cycle is 20 days with a preoviposition period of 3 days. In Burma the larval period is 10–17

days, the pupal period 6–8 days and the total life-cycle averages 19 days. The average larval period of the host at this season is about 3 days longer than that of the parasitic larva. *D. argenteo-pilosa* probably remains dormant in the hibernating caterpillar through the cold months, pupating and emerging in March.

Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 8, pp. 158, 159, fig. 2.

Garthwaite and Desai, 1939, *tit. cit.*, v, No. 4, p. 331.

Dioctes gardneri, 7 mm., is a solitary endoparasite of the 2nd and 3rd instars of *Hyblaea puera*, emerging to form an isolated cocoon. The cocoon-stage last 6 to 8 days in June. The degree of parasitism of *H. puera* by *D. gardneri* is ordinarily low but may rise very considerably in the absence of *Sturmia inconspicuella*. It was imported into Burma from south India in 1938.

Echthromorpha notulatoria on *Hapalia machaeralis* and *Hyblaea puera*. This widespread species is the most abundant of Indian Pimplinae in Peninsular India and Burma and is an endoparasite of the pupa which is stabbed through its covering leaf or cocoon. One egg is laid in each host and one female [fig. 146] may lay 80–90 eggs during a long life extending to 125 days. The life-cycle including a previposition-period of 3 days is 15–19 days in August, September, which is a few days shorter than that of the host.

Garthwaite and Desai, 1939, *tit. cit.*, v, No. 4, pp. 332, 334, fig. 4.

Edrisa pilicornis on *Microplitis maculipennis* (Braconidae) parasitising *Achaea janata* (Noctuidae).

Enicospilus atricornis on *Sylepta derogata* (Pyralidae). **E. dasychirae** on *Dasychira grotei* (Lymantriidae). **E. flavoplagiatus**, 20 mm., on *Eupterote geminata*, hibernates in the caterpillar and emerges in May in North India. **E. merdarius**, a European species, attacks *Euproctis fraterna* and *E. scintillans*. **E. rufus** on *Dasychira mendosa*. **E. striatus** on *Thiacidas postica*. (All hosts are Lymantriidae).

Ephialtes disparis, a European species, oviposits in the mature larva of *Malacosoma indica* in the Himalayas in April and emerges from the cocoon of the host in May; it includes other Lasiocampidae, Papilionidae and Pieridae among its hosts in temperate regions. **E. iridipennis** is an ectoparasite of the larva of *Sphenoptera aterrima* (Buprestidae) when boring in the bark of *Cedrus deodara*; it pupates in a tough cocoon which is flattened into an oval disc or lozenge with vertical sides and the adult emerges in spring. **E. poesia** also parasitises the mature caterpillar of *Malacosma indica* and emerges in May after a few weeks.

Exochus semiflavus on *Myelois atelogramma*, one parasite in each host.

Henicospilus see **Enicospilus**.

Hyposoter lymantriae, 7 mm., attacks *Lymantria concolor* in the early larval instars during June–July; the parasite matures in August and the host in September–October in the Himalayas.

Leptobatopsis lepidus on *Lygropia quaternalis* (Pyralidae).

Melcha nursei on *Clania crameri* (Psychidae), *Earias fabia*, *E. insulana*, and *Plusia orichalcea* (Noctuidae), *Sylepta derogata* (Pyralidae). This species is one of the commonest of the parasites of the pupae of cotton bollworms in the Punjab. The host is ordinarily attacked after pupation but also the full-grown caterpillar may be visited as soon as the cocoon is formed. Oviposition is a long process sometimes lasting an hour. One female may oviposit in 120 pupae. The egg takes a day to hatch in October and up to 6 days in December–March. The parasite feeds externally on the pupa, one individual reaching maturity on each host. The larval stage lasts about a month in the cold season. Pupation takes place in the cocoon of the host and the pupal stage lasts 3 weeks in February but only one week in August. The life-cycle from oviposition to emergence of adult is 2 weeks in August–October, extending to 2 months in the cold weather, one month in February–March, 3 weeks in March. At Delhi the life-cycle varies from 17–20 days at 24°C. to 37–43 days at 16°C. at 100 percent humidity. The life of the adult is 15–40 days; its vital limits of temperature and humidity are identical with those of *Microbracon greeni* race *lefroyi*.

Ahmad T., 1940, *Proc. 27th Ind, Sci. Congr.*, III, pp. 166, Development and fecundity of Melcha nursei.

Husain M. A., 1924, *Proc. 5th Ent. Meet., Pusa*, Feb. 1923, pp. 46-49.

Mesochorus facialis is hyperparasitic on *Lymantria concolor* (Lymantriidae), *Achaea janata*, (Noctuidae), *Euthalia garuda* (Nymphalidae), *Bocchoris artificialis* and *Pycnarmon caberalis* (Pyralidae). **M. indica**, 2·7 mm., is a hyperparasite of *Hapalia machaeralis* and *Hyblaea puera* through *Apanteles machaeralis* and *A. malevolus* (Braconidae). The feeding-period is at least 7 days and the cocoon-period 7 or 8 days in July–October. With the advent of cold weather the cocoon-stage is prolonged to 2 or 3 weeks and the parasite hibernates, as does the host, during the coldest months. **M. plusiaephilus** on *Apanteles malevolus*, *A. plusiae* (Braconidae). The parasitised *Apanteles* larvae emerge from the host-caterpillar and spin cocoons normally.

Microtoridea lissonota in parasites of *Achaea janata* (Noctuidae), *Sylepta derogata* (Pyralidae). **M. secunda**, 2·7 mm., a solitary endoparasite of *Apanteles importunus*, *A. machaeralis*, *A. obliqua niger* (Braconidae). The parasitised *Apanteles* larva emerges and spins its cocoon in which *M. secunda* develops for 24 to 35 days in November–January and about 21 days in February; cocoons formed in January or February remain for 11 and 6 weeks respectively before the adults emerge.

Nemeritis tectonae is a parasite of the beehole borer, *Xyleu-*

tes ceramica (Cossidae), in parts of Burma but is not uniformly distributed in the habitat of teak. The early stage caterpillar of *ceramica* is attacked and killed before it is able to make more than a short tunnel of small diameter. After a larval life of 6 weeks the parasite pupates in the tunnel in a tough dark brown silk cocoon and emerges after 18 days pupal period in April, May. Only the accessible beeholes in small diameter teak saplings, or in the upper parts of the bole and crown of older teak trees, are attacked. The total percentage-parasitism of beeholes is greatest in young trees and decreases as the trees grow older, the higher beeholes being more abundantly attacked than lower ones. The percentage-parasitism may be maintained at a high level in the small diameter wood in the crown branches throughout the life of the tree. It parasitises alternate hosts in the period August–May when larvae of *X. ceramica* are inacessible and not in the right stage for parasitisation. The chief alternate host is *Indarbela quadrinotata*, a bark-eating caterpillar of many leguminous trees and their associated species. The importance of this parasite as an agent in the biological control of the beehole borer depends on the abundance of those species of trees that support bark-eating caterpillars.

Annual Reports For. Ent., Burma for 1938-39 and later.

Neopimploides syleptae in *Sylepta derogata* (Pyralidae).

Ophion areolatus in *Acronycta maxima* (Noctuidae). The life-cycle is annual conforming to that of its host, passing the winter in the pupa and emerging at the end of the dry season in the hills in India.

Paniscus testaceus in *Prodenia litura* (Noctuidae). This is a common polyphagous widespread parasite known in Europe to parasitise members of nearly every family of the Macrolepidoptera but known only from one host in India. The egg has a long stalk by which it is attached to skin of the host. The parasitic larva feeds at first in the shelter of the eggshell absorbing liquid food through a hole in the skin. If the host pupates or forms a cocoon before dying the parasites spin up inside the larger cocoon.

Pristomerus laccae, 6 mm., probably parasitic on *Holcocera pulverea* (Blastobasidae), predaceous on the lac insect. **P. microdon,** 6·5 mm., on *Apanteles* sp. and *Microgaster indicus.* (Braconidae). The primary parasite emerges from the caterpillar of *Hapalia machaeralis* and forms a normal cocoon from which *P. microdon* emerges after 7 or 8 days in July and 8 days in September.

Pristomerus testaceicollis. An endoparasite of the caterpillar of the lac predator, *Holcocera pulverea* and, after *Apanteles tachardiae*, the most important enemy of the predator. Only one parasite develops in each host and when full grown emerges to prepare a brownish-white cocoon. There are at least 4 generations a year. It is most abundant in the cold weather, November to

March, i.e., in the mature Aghani and Katki lac crops. The female lives for over 80 days in the cold weather, and 15–30 days in the hot season.

Annual Reports of the Indian Lac Research Institute.
Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No. 8, pp. 165, 166 (synonymy).
Mahdihassan S., 1937, *Curr. Sci.*, pp, 119 (fig. female),

Rhyssa persuasoria himalayensis on *Sirex imperialis* (Siricidae). The female *Rhyssa*—a slender black and yellow (or pinkish yellow) insect with body ½ to 1 inch long and an ovipositor as much as 1½ inches long,—locates siricid larvae in the wood of dead conifers by examination of the bark from the outside. In order to bore through the bark and wood down to the larval gallery the abdomen is raised vertically as high as possible and the ovipositor turned along the ventral surface between the coxae bringing it at right angles to the surface of the tree. The stylets are gradually worked through the wood-tissues leaving the sheath outside; the procedure takes half an hour to several hours. Under difficult circumstances the *Rhyssa* may fail to withdraw the ovipositor after egg-laying and is thus entrapped The egg is laid in the tunnel near the almost or quite full fed larva (or the pupa) of *Sirex*, which at the end of its feeding period is within one or two inches from the surface of the tree. The parasite on hatching feeds externally and is full fed in a few weeks during which the host larva may burrow a little further. The remainder of the annual cycle is passed by *Rhyssa* as a resting larva with pupation in the following spring. The wasp emerges by excavating a direct tunnel with a circular exit-hole. Pairing takes place immediately after the female has emerged.

Stebbing E, P., 1903, *Dept. Notes* No. 2, pp. 156-158, pl. vii, fig. 2 (as Thalessa or Rhyssa sp.).
Beeson and Chatterjee S. N., 1935, *Ind. For. Rec.*, Ent., I, No 8, pp. 166, 167,

Siphimedia lutea on larva of *Rhadinomerus malloti* (Curculionidae).

Syzeuctus zanthorius on the caterpillar of *Dichocrocis leptalis*, *Jocara malefica*, *Lygropia quaternalis* (Pyralidae).

Theronia zebra on *Hyblaea puera*, Bengal to Java

Trichomma nigricans on *Hapalia machaeralis* in south India.

Trophocampa indubia on *Botyodes asialis*, *Hapalia machaeralis*, *Lamprosema diemenalis*, *Pyrausta celatalis* (Pyralidae). This species oviposits in the caterpillar of *Hapalia machaeralis* when in the 3rd instar (7 or 8 days old). The larva is endoparasitic, one in each host which dies before pupation. The life-cycle from egg to emergence lasts 14–16 days in April (larva 7 or 8 days, cocoon 7 or 8 days). Mating and oviposition take place within 2 or 3 days of emergence. Pairing lasts about 3 minutes. In October the cocoon-period requires 5 to 7 days. In Dehra Dun

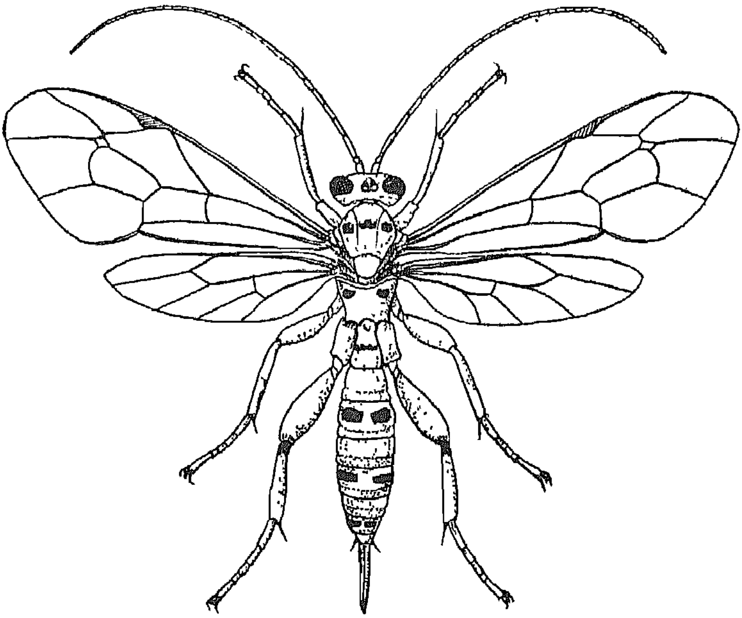


Fig. 147. Xanthopimpla cera, 10 mm.

in November the parasite may leave the host and form its cocoon and the adult emerges in 13-18 days but normally the parasite hibernates in the body of the *machaeralis* caterpillar for 4 or 5 months, November to March or April. Cocoons of the first generation formed in March yield adults in 7 to 9 days. From parasitised *Lamprosema diemenalis* the wasp emerges in February after a cocoon-period of 21–24 days.

Xanthopimpla cera [fig. 147]. A parasite of the pupa of *Hapalia machaeralis*, one individual developing in each host, and emerging 3 or 4 days later than the day on which the moth would normally emerge.

Xylonomus caerulescens in *Xylotrechus quadripes* (Cerambycidae) in south India.

Zamesochorus orientalis in *Achaea janata* (Noctuidae).

MEGACHILIDAE

MEGACHILE includes the Leaf-cutting Bees of which **Megachile anthracina** is one of the commonest species. The female bee cuts with its mandibles oval or circular pieces from the edges of leaves of trees, which are used to form cells for the larvae in the nest, (which is solitary as opposed to the compound nests of the of the social bees). A cylindrical shaft is excavated in rotten wood, or in the soil, or natural tubes such as bamboos and hollow

twigs are used. Several shaped pieces of leaf are cemented together to form the lining of each cell, which is provisioned with honey and pollen. An egg is laid on the food-mass and the cell closed. A series of cells placed end to end fills up the tunnel. The larvae feed on the food-supply and pupate in the emptied cell. The defoliation is scarcely of economic importance.

MISCOGASTERIDAE

Mani M. S., 1938, *Catalogue Ind. Ins.*, Part 23. Chalcidoidea.

Bruchobius colemani and **B. laticeps** are parasites of species of *Bruchus*.

Dinarmus sauteri is a parasite of the larva of *Lixus truncatulus* (Curculionidae) in Amaranthus. The life-history is described by T. Ahmad, 1939, *Ind. Journ. Agr. Sci.*, IX, pp. 624, 625, pl. XXVII, figs. 10, 11.

Oedaule stringifrons in larvae of *Pachymerus gonagra* (Bruchidae).

PERILAMPIDAE

Mani M. A., 1938, *Catalogue Ind. Ins.*, Part 23 Chalcidoidea.

Monacon abruptum, length 2·5 mm., is parasitic on *Platypus uncinatus* (Platypodidae).

Monacon productum, length 3·0 mm., is an enemy of *Diacavus furtivus* (Platypodidae). The parasitic wasp presumably enters the tunnels of the shothole borer when the brood is developing and oviposits near the mature larva.

Perilampus hedychroides is a hyperparasite; the hosts are *Sturmia inconspicuella* and *Zenillia roseanellae* (Tachinidae) and one braconid and one ichneumonid parasitic on *Hapalia machaeralis* (Pyralidae). One individual emerges from each host puparium or cocoon. The life-cycle lasts about 34 days in August, September.

Garthwaite P. M. and Desai M. H., 1939, *Ind. For. Rec.*, Ent., v, 4, p. 342.

Perilampus microgastris, black, 1·5–3 mm. long, is parasitic on *Cremastus hapaliae* and other ichneumonids and on *Apanteles machaeralis*, *A. stantoni*, *Macrocentrus trimaculatus*, *Microgaster indicus*, *Microgaster plecopterae*, *Phanerotoma hendecasisella* (Braconidae) and other braconids in India and the Oriental Region; also on *Entorocca fasciata* (Tachinidae) and several braconid and ichneumonid parasites of *Lygropia quaternalis*, *Sylepta balteata* (Pyralidae). The braconids parasitic on *Hapalia machaeralis* are infected by *P. microgastris* while in the host caterpillar and they escape and spin cocoons normally. One hyperparasite emerges from each host-cocoon. The duration of the cocoon-stage of *P. microgastris* in May is 11–20 days (mode 12 days), in June to August is 11–26 days, whereas the normal cocoon-period for the braconid host is 5–8 days; in November and

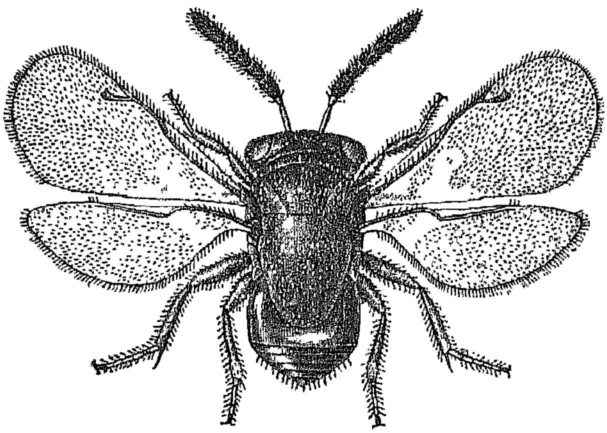


Fig. 148. Scutellista cyanea, 1·2 mm.

December these periods are prolonged to 56 and 19 days respectively.

Beeson and Chatterjee S. N., 1939, *Ind. For. Rec.*, Ent., v, 5, p. 377.

PTEROMALIDAE

Mani M. S., 1938, *Catalogue Ind. Ins.*, Part 23, Chalcidoidea.

Agiommatus acherontiae is a parasite of the eggs of *Acherontia styx* (Sphingidae). In north India in May eggs of this hawkmoth take 6 days or less to hatch, but if attacked yield parasites after 10–11 days. The egg measures 1·8 × 1·6 mm. and the adult parasite measures 2·4 mm. (female) and 1·4 mm. (male).

Cerocephala dinoderi is parasitic on *Dinoderus minutus* (Bostrychidae).

In the genus **Prospaltella** are parasites of Coccidae and Aleyrodidae.

Dibrachys near **cavus** is hyperparasitic on *Ectropis deodarae* (Geometridae) through ichneumonids, emerging from the pupa in July.

Eutelus near **subfumatus** is hyperparasitic on *Ectropis deodarae* (Geometridae) through ichneumonids emerging from the pupa in July.

Pachyneuron pentatomivora is parasitic on the eggs of *Urostylis punctigera* (Pentatomidae). The female is 0·75 mm. long; the male is figured by Mani, 1939, *Ind. Journ. Ent.*, I, p. 82, fig. 3.

Roptrocerus sulcatus, length 5·5 mm. but variable, is a parasite of *Ips longifolia* (Scolytidae). The eggs are deposited in the tunnels of the bark-beetle; in thin-barked twigs they may be inserted from the outside by means of the ovipositor. The larva feeds externally to the host and pupates naked in the gallery of the

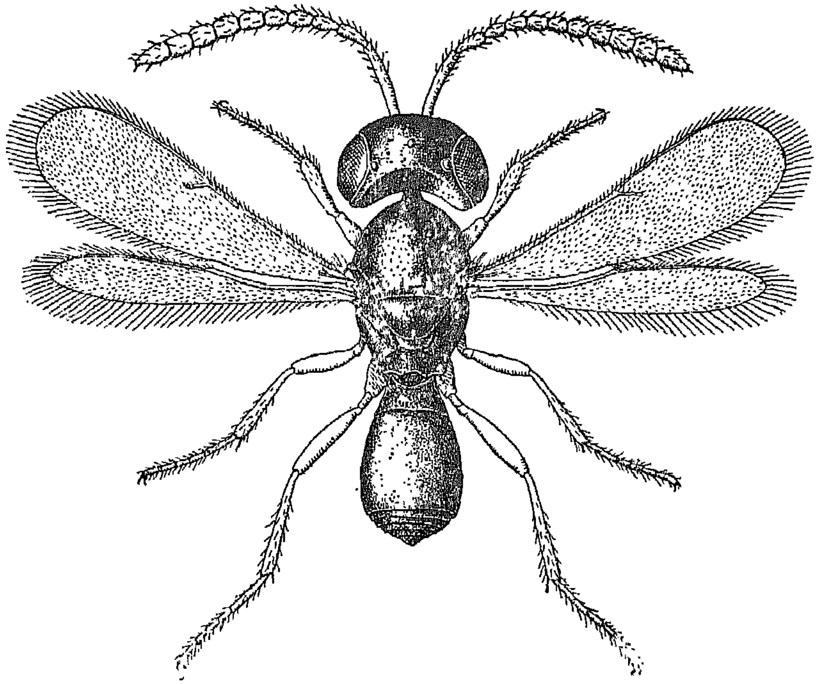


Fig. 149. Telenomus usipetes, 0·5 mm.

host-larva or in the adjoining aeration-shafts. The life-cycle corresponds to that of the host.

Scutellista cyanea, length 1·2 mm., [fig. 148], is a widely distributed parasite of scale-insects, e.g., *Saissetia oleae*, *S. nigra*, *Ceroplastes* and *Phoenococcus* (Coccidae).

SCELIONIDAE

LITERATURE ON SCELIONIDAE:

Pruthi H. S. and Mani M. S., 1941, *Imp. Counc. Agr. Res., Misc. Bull.*, Biological notes on Indian Serphoidea (Proctotrupoidea) and Bethyloidea.

Aholcus euproctiscidis, 0·85 mm., is parasitic on eggs of *Euproctis lunata* (Lymantriidae). The life-cycle is about 8, 9 days in August, September. Mani, 1939, *Ind. Journ. Ent.*, I, p. 95, fig. 9 *a b*.

Species of **Scelio** are parasitic on the eggs of locusts and grasshoppers, e.g., **S. atractomorphae** on the eggs of *Atractomorpha crenulata*, **S. hieroglyphi** on *Hieroglyphus banian* and **S. oxyae** on *Oxya velox* (Acridiidae), all in India.

Telenomus javensis is a parasite of the egg of *Lixus truncatulus* (Curculionidae) and **T. proditor** of the egg of *Eupterote*

undata in India. Other species of **Telenomus** are parasites of eggs of Rhynchota.

Telenomus usipetes, [fig. 149], is parasitic on the eggs of *Hapalia machaeralis* and *Hyblaea puera.* Parasitised eggs turn yellow on the 4th or 5th day. The life-cycle ranges from 8 to 15 days with an average of 10 days. It breeds twice as fast as the host. A parasitism-percentage of 12 has been noted in the field for *Hapalia machaeralis*, and of under 1 for *Hyblaea puera.*

Garthwaite and Desai, 1939, ***Ind. For. Rec.***, Ent., v, 4, p. 348, fig. 6.

SCOLIIDAE

NUMEROUS species of this family of Hairy Flower-wasps are ectoparasites of the larvae of Scarabaeidae in soil and rotten vegetable matter and a few have been imported from one country to another for use in the biological control of injurious grubs. **Tiphia matura** lays an egg on the grub of *Popillia cupricollis* (Scarabaeidae) inserting it between the 8th and 9th abdominal sternites. There is a single annual generation passing the winter as an adult in its cocoon in the soil and emerging in April-June.

Bingham C.T., 1897, ***Fauna Brit. Ind.***, Hymenoptera, I, pp. 56-102, Scoliidae.

SERPHIDAE

MANY species of this family are parasites of the larvae of Diptera (Muscidae, Mycetophilidae, Phoridae) and of Coleoptera (Carabidae, Coccinellidae, Staphylinidae).

Pruthi H. S. and Mani M. S., 1941, ***Imp. Counc. Agr. Res., Misc. Bull.***, Biological notes on Indian Serphoidea.

Serphus gravidator is parasitic on the soil-dwelling larva of *Nebria cameroni* (Carabidae). The *Serphus* larva emerges partially from the anal extremity of the host larva and then pupates without the formation of a cocoon ; the pupal period is about 10 days.

Gardner 1929, *Ind. For. Rec.*, XIV, IV. p. 107, fig. 1.

SIRICIDAE

WOODWASPS of this family occur in the Himalayas but very little is known of their ecology.

Sirex imperialis, a large metallic blue and reddish-brown, hairy woodwasp, $1\frac{1}{4}$ inches, which bores logs of *Abies webbiana*, *Cedrus deodara* and *Picea morinda* in the Himalayas. The ovipositor of the female is 18 mm long and able to penetrate thick bark in order to deposit eggs in the wood. The larva tunnels long and deep in the wood, filling the tunnels with fine and tightly packed wood-dust ; the mature instar is yellow, $1\frac{1}{4}\times\frac{1}{8}$ inches, somewhat cylindrical with a hooded pronotum, vestigial thoracic legs and a dark spinose spike ending the abdomen. The larval period is approximately one year and may be prolonged to a second season. Pupation occurs at the end of the larval tunnel near the surface and in May, June the wasp emerges by boring straight to

the outside leaving a circular exit-hole ¼ inch in diameter. The damage done to timber in a heavy attack spoils it for internal constructional work and reduces its durability for outdoor service. Extensive tunneling is associated with and is probably dependent on the growth of wood-rotting fungi.

Bradley J. C., 1934, *Rec. Ind. Mus.*, XXXVI, ii, p. 145, A new species of Xeris from the Himalayas.

SPHECIDAE

An extensive family of fossorial wasps (previously named Sphegidae) making cells of mud in which paralysed caterpillars, crickets, cockroaches, grasshoppers, spiders, etc. are stored for the larval food-supply.

Bingham C. T., 1897, *Fauna Brit. Ind.*, Hymenoptera, I, pp. 179-330, Sphegidae.
Dutt G. D., 1912, *Mem. Dept. Agr. Ind.*, IV, pp 198-229, figs. 5-13.
Hingston R. W. G., 1928, *Problems of instinct and intelligence.*

Ampulex compressa captures cockroaches. **Sceliphron deforme** captures spiders; for life-history see Edwards S. B. 1921, *Journ. Bomb. Nat. Hist. Soc.*, XXVIII, pp. 293-297, fig. **Sphex lobatus** captures crickets (Gryllidae); for life-history see Hingston R. W. G , 1925, *tit. cit.*, XXX, pp. 743, and XXXI, pp. 147-157.

Stigmus congruus and **S. *niger*** store aphids.

TENTHREDINIDAE

Sawflies are more abundant in the hills in temperate climates than in the plains in India; they have been generally neglected and food plants are known of very few species of sawfly larvae. The life-history of **Athalia lugens proxima**, a plains species feeding on Cruciferae, is given by Lefroy H.M. and Ghosh C. C., 1908, *Mem. Dept. Agr. Ind.*, Ent., 1, pp. 357-370, pl. XX. **Cibdela janthina** defoliates *Rubus ellipticus* and *R. lasiocarpus.* Eggs are laid in single rows partially inserted in a slit in the midrib or thick side-vein of a leaf and hatch in 6-7 days (in August). The larvae feed gregariously in groups of 1-2 dozens per leaf and consume it completely. The mature larva is light green with purplish tinges, black dotted, 22 mm. long, with 5 pairs of abdominal prolegs; the abdomen is usually held curled over the thorax in a **U** or **S** shape After a larval period of 3 weeks double cocoons, 13 × 8 mm., are spun in a cluster; the pupal period is 14-17 days. The total life-cycle in the monsoon season is about 6 weeks, but this generation and others may vary widely in length, some individuals taking 20-24 months with a prolonged resting stage in the cocoon.

Malaise R., 1932, *Spol. Zeylan.*, XVII, pp. 147, 8, A new sawfly from Ceylon.
— 1934, *Rec. Ind. Mus.*, XXXVI, iv, pp. 435-474, On some sawflies from the Indian Museum, Calcutta.

TORYMIDAE

Mani M. S., *Catalogue Ind. Ins.*, Part 23, Chalcidoidea, pp. 32-45, 145.
Pruthi H. S. and Mani M. S., 1940., *Imp. Counc. Agr. Res., Misc. Bull.*, 30,

Ormyrus orientalis is parasitic on the larva of *Ophiomyia lantanae* (Agromyzidae).

Pachytomus mantisphagus, Podagrion mantoidae and **P. pachymerum** are parasites of the egg-masses of Mantidae.

TRICHOGRAMMATIDAE

ONLY 12 species of this chalcidoid family are recorded from India nevertheless it is universally familiar on account of the importance of a few species in the biological control of several pests. They are the egg-parasites and among the smallest of the chalcidoids.

Mani M. S., 1938, *Catalogue Ind. Ins.*, Part 23, Chalcidoidea.
Pruthi H. S. and Mani M. S., 1940, *Imp. Counc. Agr. Res., Misc. Bull.*, No. 30, pp. 31, 32, Trichogrammidae.

Trichogramma evanescens (including the well-known name *Trichogramma minutum* Riley, which is now ranked as a variety). This egg-parasite has been extensively used in biological control of pests in many parts of the world. Its hosts include the eggs of over 50 species of 15 families of Lepidoptera, about 10 species of Hymenoptera and 12 species of other orders. A female oviposits through the chorion of the egg (which may be considerably larger than the *Trichogramma*) taking a few minutes to bore through. The length of the life-cycle from oviposition to emergence is largely dependent on temperature. In south India in May it is completed in 6 days. At average temperatures from 15·5°–21°C. the ratio of change is an increase or a decrease of about one day for each 0·7°C. decrease or increase in average temperature. The maximum rate of reproduction occurs at 27°C. and 70–80 percent relative humidity. At an average life-cycle of 7 days it is theoretically possible for 52 generations per annum to be obtained under optimum conditions (Flanders). The numbers of individuals that can develop in one host-egg depends on its size. The female can lay 35–40 eggs. The conditions governing the actions of the female in the discovery, selection and oviposition of different species of host-eggs have been thoroughly studied. The behaviour of the different varieties or biological races of *evanescens* is well known. These data have been applied to practical methods of mass-production of *Trichogramma* with considerable success. Eggs of the flour moths, *Sitotroga cerealella* and *Corcyra cephalonica*, are generally used for artificial rearing of the parasite; in India the moths are reared on wheat bran, gram, cowpea, jola, etc. For details of the technique consult Subramaniam and Rao, 1937, and King, 1933. *T. evanescens* has been liberated for the control of sugar-cane borers, spotted bollworms of cotton, coffee tortricid, teak defoliators and pests of tea and lac in India and Ceylon. In 1937–38 in Mysore 11,000,000 parasites were released in operations against sugar-cane borers.

LITERATURE:
An extensive bibliography of *evanescens* and *minutum* is given in Mani, 1928, *Catalogue Ind. Ins.*, pp. 136-140. Some of the more important general references in Ceylon and Indian scientific journals are:—
Ayyar T. V. R. and Margabhandu V., 1934, *Journ. Bomb. Nat. Hist. Soc.*, XXXVII, p. 196 (Hosts in India).
Beeson and Chatterjee S. N., 1939, *Ind For. Rec.*, Ent., v, No. 5, p. 379.
King C B R., 1933, *Bull. Tea. Res. Inst., Ceylon*, No. 10, pp. 27-33 (Introduction of *T. evanescens* and breeding in Ceylon).
Subramaniam T. V., 1937, *Ind. Journ. Agr. Sci.*, VII, pp. 149-155, Preliminary experiments on the mass production of Trichogramma parasites for control against sugar-cane borer in Mysore.
Subramaniam T. V. and Rao D. S., 1940, *Dept. Agr. Mysore*, Ent. Bull. No. 12, Technique for the mass breeding of the flour moth Corcyra cephalonica.
H. S. P., 1939, *Ind. Journ. Ent.*, I, pp. 115, 116, Host selection by insect parasites.

Trichogrammatoidea nana is an egg-parasite of various species of Noctuidae, Pyralidae and Tineidae including *Hapalia machaeralis*, *Corcyra cephalonica*, *Ephestia* sp., *Sitotroga cerealella*, *Eublemma amabilis*, *Hyblaea puera*, *Holcocera pulverea* and *Diacrisia obliqua*. Parasitised eggs turn black 3 or 4 days after parasitism. The life-cycle ranges from 6 to 13 days, the average for the year being about 9 days. The adult lives about 6 days. Experiments have been conducted in Burma and Madras in mass rearing of this species for the control of the teak defoliators. Thirty generations of this egg-parasite have been obtained in a year. It has also been studied at the Lac Research Institute for the control of lac predators, being bred on eggs of *Ephestia* sp.

Garthwaite P. F. and Desai M. H., 1939, *Ind. For. Rec.*, Ent., v, 4, p. 350 (under *Trichogramma* sp.).
Annual Reports of Lac Res. Inst. from 1938.

VESPIDAE

WASPS and Hornets are social insects making nests of plant or wood-pulp scraped from surfaces of decayed wood, twigs, bark, etc., chewed and moulded into hexagonal cells hanging vertically with the opening downwards; "...in the simple nests of *Icaria* there are two rows of cells only; in the more complex nests of *Polistes*, the cells form horizontal combs, hung by stalks, and with a diameter of six or more inches in rare cases; there may be one comb below another but the combs are open all round. In *Vespa*, there is an envelope, the nest completely enclosed and with the combs inside clear of the envelope so that there is access to each comb all round; in others the comb is attached to the envelope and access is gained by a central space passing through the combs." (Lefroy). The wasp larvae live each in one cell and are fed by the adults on chewed insects, plant-sap, sugars, etc. The food differs from that of Apidae in that it consists largely of animal matter. Only the female has a poisonous sting.

LITERATURE:
Bingham C. T., 1897, *Fauna Brit. Ind.*, Hymenoptera, I, Wasps and Bees.

Dover C., 1922, *Journ, As. Soc. Beng*, XVIII, pp. 17–23, Resume of recent progress in our knowledge of Indian wasps and bees.

Polistes hebraeus is the yellow house-wasp making a single-storeyed nest suspended by a central stalk; it is injurious in offices and libraries, destroying paper labels, notices, file-covers, books, etc.; only the paper is removed: ink, paint, glaze, etc. are untouched. **P. stigma** is a similar, less ubiquitous house-wasp.

Vespa includes Hornets which are predaceous on various kinds of insects, including honeybees and defoliating caterpillars, and also avid feeders on sweet stuff. **V. basalis** kills twigs and branches of trees by gnawing away the bark in patches and rings, removing it layer by layer until the wood is exposed; the chewed material is used in the fabrication of the nest. Among the species of trees chosen are *Calliandra houstoniana*, *Eucalyptus* spp., *Poinciania regia*, *Schrebera swietenioides*, *Tecoma stans.* A tree is visited continuously for several weeks. **V. cincta** is a hornet commoner in jungle and forest than is **V. orientalis** which is abundant in bazaars.

XIPHYDRIIDAE

WOODWASPS closely allied to the Siricidae. The habits of only one species have been recorded;—**Xiphydria heritierae** bores the wood of *Heritiera fomes* in Bengal making abundant closely interlaced tunnels and emerging in March.

Beeson, 1919, *Ind. For. Rec.*, VII, v, p. 6.

XYLOCOPIDAE

XYLOCOPA comprises the Carpenter Bees, which are large insects with broad, stout, shining, black bodies about an inch long, and with fuscous wings giving metallic reflections and spanning 2–3 inches. There is a short black velvety pubescence on parts of the body and long dense hairs on the legs; the legs of the male are rather elongate. One species, *aestuans*, has bright yellow pubescence on the thorax.

The bees bore energetically into dead branches and trunks of trees, and enter buildings where they bore into posts and rafters; soft even-grained timbers such as *Adina cordifolia*, *Eugenia jambolana* and *Ficus* spp. are preferred. Hollow bamboos and reeds are also used. The tunnels [fig. 150] are more or less cylindrical, an inch to 1½ inches in diameter, and up to 8 inches long with short branch-tunnels. In these a series of cells is constructed by cross-partitions made of wood-dust kneaded with saliva; in each cell an egg is laid and a store of pollen, or bee-bread, in a ball ½ an inch to 1 inch in diameter is provided as food for the larva. The larva finishes feeding in about 3 weeks and pupates in the cell and the resulting bee eventually gnaws its way out after a life-cycle of 6 weeks.

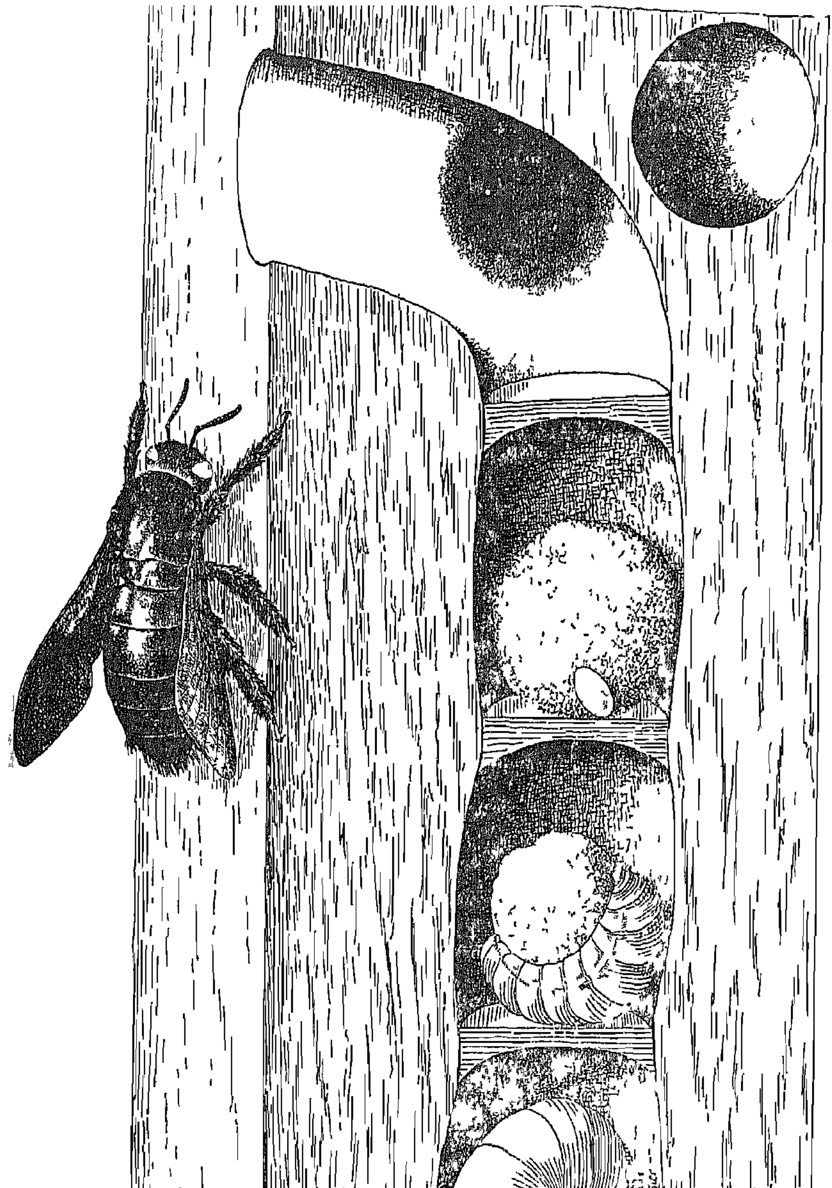
A colony of carpenter bees that has occupied a piece of timber continues for several generations until the wood is completely perforated and riddled with tunnels. The parent bees inhabit the tunnels while the larvae mature and hibernate in them during the cold weather and if disturbed they emerge and fly around in an alarming manner, but apparently do not sting. In forest rest-houses and wooden bungalows they are a nuisance, not only on account of the damage done to rafters and beams, but also on account of the wood-dust and other refuse dropped out.

Beeson, 1938. *Ind. For.*, LXIV, pp. 735-737, pl. 57.
Tsing-chao Ma, 1938. *Rec. Ind. Mus.*, XL pp 265-329, figs. 14, The Indian species of the genus Xylocopa Latr.

Xylocopa aestuans is about 7/8ths of an inch long with a wing-expanse of $1\frac{3}{4}$ to 2 inches. The head and body in the female are black with a long bright yellow pubescence on the thorax; the male is entirely covered with a short dull yellow pubescence, longer on the thorax. According to Ma(1938) this species should be named *leucothorax* de Geer. It occurs throughout India and in north Africa. The tunnels are bored by both sexes in dead wood or in the timber used in buildings. When crowded they branch very much without definite arrangement. The larval cell contains a ball of bee-bread about $\frac{1}{2}$ an inch in diameter and one egg, and is closed by a partition of fine wood-dust amalgamated with viscous saliva; each partition is thinnest near its middle. This bee is occasionally a nuisance in forest resthouses boring into roofing rafters, posts and bamboos. It also nests in the dead branches of *Ficus* spp. and *Camellia thea* and in timber depots in old wood of *Cordia grandis, Manglietia caveana, Michelia oblonga, Pterocarpus dalbergioides*, etc.

X. latipes, is broad-bodied, black and moderately shiny in both sexes; length $1\frac{1}{4}$ inches; the wings are fuscous with metallic blue-green and purple reflections; expanse 3 inches. It is inactive from November to March in the warmer parts of India and for a longer period in the colder regions. It hibernates in tunnels bored in wood, bamboos or reeds. In timber the bee bores a tunnel that turns downwards in upright or vertical posts and beams [fig. 150], or may turn in any direction in horizontal beams and logs; the main tunnel may have 2 to 6 offshoots, 2 to 4 inches long and $\frac{3}{4}$ inch in diameter. The bore of the tunnel is nearly cylindrical being slightly constricted at intervals to form separate cells. In hollow bamboos of the right diameter the bee enters at the cut or broken end and makes a single series of cells. At the end of each tunnel a single egg is laid and a store of bee-bread or pollen is added; the cell is then closed by a partition of fine wood-dust scraped from the sides and amalgamated with saliva. The partition is biconcave leaving a thin central portion. Other cells are constructed successively above the previous ones.

The egg hatches in warm moist weather in 6-7 days. The



larva feeds on the bee-bread and pupates in about 3 weeks. The pupal period lasts about 15 days and the bee after a short period of maturation bores out straight to the surface by a separate tunnel or follows that constructed by the mother-bee. The total life-cycle is about 6 weeks. During this time the parent bees remain guarding the larval cells or are occupied in constructing additional tunnels. There are 4 generations or broods between March and November.

One of the earliest illustrations of the damage done by this bee is given by Cleghorn, 1861, *Forests and Gardens of South India*, pp. 15, 70, pl. 2. In addition to attacks on constructional timber of *Amoora wallichii*, *Cinnamomum glanduliferum*, *Cedrela toona*, *Dysoxylon hamiltonii*, *Eugenia jambolana*, and *Terminalia chebula*, it is recorded as boring holes in lead cables. A hundred years ago it was a very prevalent pest of wooden buildings.

X. nasalis is a broad black bee including subspecies and varieties previously known as *auripennis*, *dissimilis* and *iridipennis*; length $1\frac{1}{4}$ inches; expanse of wings $2\frac{1}{2}$ to $2\frac{3}{4}$ inches these are purple with metallic green apical bands. Sometimes a nuisance in forest resthouses boring into roofing rafters, posts (*Adina cordifolia*) and bamboos (*Bambusa tulda*, *Dendrocalamus* sp.). The subspecies *nasalis nasalis* occurs in Malaya, China and upper Burma and subspecies *nasalis auripennis* throughout India, Burma, Ceylon, Malaya. Notes on its habits in China are given by Hoffman, 1938, *Lingnan Sci. Journ.*, 17, pp. 87–91, figs. 1, 2 (as *X. dissimilis*).

X. tenuiscapa is an all black stout-bodied species closely resembling *latipes*; length $1\frac{1}{4}$ inches; expanse of wings $2\frac{3}{4}$ inches; occurs throughout India, Ceylon and into China. Its tunnels are similar to those of *X. latipes* running parallel to the long axis of the log or beam, about 4 or 5 inches long and 1 inch in diameter with short offshoot tunnels. The larval chamber is provided with a ball of bee-bread $\frac{1}{2}-1$ inch in diameter, and is closed by a plug of pieces of leaf. [fig. 150]. It is a pest in rest-houses and wooden bungalows attacking rafters and posts of *Adina cordifolia*, *Eugenia jambolana* and bamboos, and is active throughout the year in south India.

X. tranquebarica makes tunnels in the wood of *Albizzia stipulata*.

X. verticalis makes tunnels in bamboos, constructional timber of *Duabanga sonneratioides*, *Michelia champaca*, *M. oblonga*, *Morus laevigata* and *Terminalia procera*. Occurs in India, Andamans, Malaya.

Fig. 150. Tunnel of Xylocopa tenuiscapa in a wooden post; sectional view of cells containing bee-bread, egg and larva; the scale-line represents one inch.

ISOPTERA

THE ORDER ISOPTERA

VERNACULAR names for termites: Bengali, *ooi*, *ooli*; Gujrati *dimak*; Hindi, *dimak*; Konkani, *valati*; Marathi, *walawi*; Ooriya, *ooi*; Punjabi, *dimak*, *saink*; Tamil, *karayan*.

Out of a total world fauna of about 1600 species over 100 are recorded from the Indian region; these are classified in 3 families **Kalotermitidae, Rhinotermitidae** and **Termitidae.**

The Isoptera or termites are pre-eminently social insects living in colonies, each colony forming an independent state with a social system that is, for insects, highly developed; they have no anti-social tendencies and no unsocial behaviour. No successful social regime is possible without division of labour; this is achieved by dividing the work of the colony among *castes* or forms which are specialised in structure and behaviour. The principal castes are the reproductive forms, the workers, and the soldiers, but there are several variations of these main castes giving rise to 16 possible kinds of individuals in the termite society (see below).

Termites antedate human social development by many millions of years and have perfected an organisation that is in many respects superior. Biologically, socially and politically the termite offers an object-lesson to man and a comparison of this insect Utopia with various concepts of human government has attracted several philosophers. It has been suggested that the termite state exemplifies the totalitarian concept of government towards which dictatorships tend but can never reach. There are several essays on this subject by Bouvier, Forel, Maeterlinck, Wheeler and others, which those who are interested should read.

The castes.

The polymorphism or caste development in termites is remarkable because it is highly elaborated although the insects are primitive anatomically, and it parallels in many of its features that of the most highly specialised Hymenoptera. Wheeler distinguishes the following 8 castes with 16 different kinds of individuals :—

1. First form males and females (true kings and queens)
2. Second form males and females (neotenic substitution forms)
3. Third form males and females (ergatoid substitution forms)
4. Large male and female workers.
5. Small male and female workers.
6. Large male and female soldiers.
7. Medium sized male and female soldiers.
8. Small male and female soldiers.

It should be understood that all these castes do not occur in one and the same colony or even in one species but six of them are frequently encountered. In addition to the adult or mature stages of these castes there are also the nymphal or immature growth stages of the same.

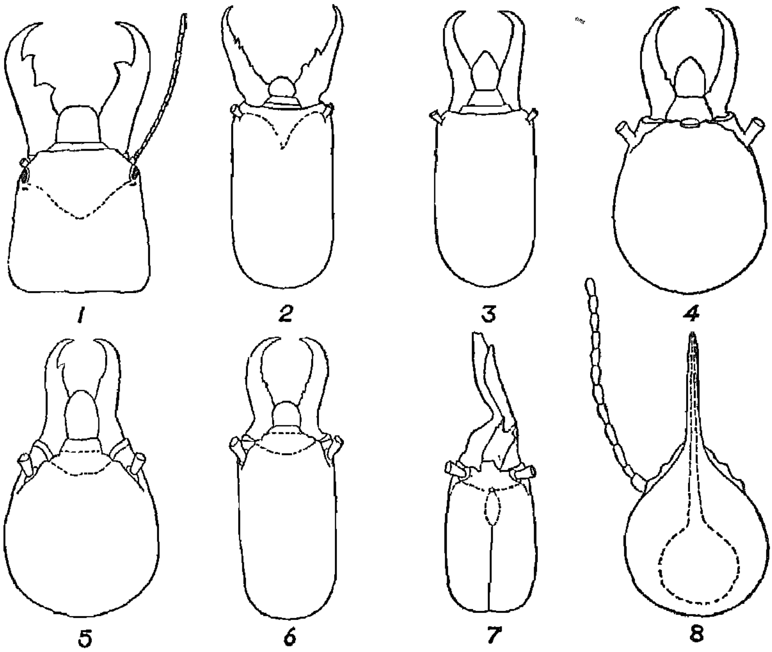


Fig. 151. **Heads of soldiers of termites.**

No. 1. Archotermopsis wroughtoni, 2. Neotermes militaris, 3. Heterotermes indicola, 4. Coptotermes ceylonicus, 5. Cyclotermes obesus, 6. Microcerotermes annandalei, 7. Capritermes obtusus, 8. Eutermes group.

The morphology and function of the castes may be generalised as follows :—

The Sexual or Reproductive Castes.

1 : The first form males and females are imagines, deeply pigmented, with large compound eyes, functional reproductive organs, and fully developed wings (macropterous, 2 pairs). After use in a swarming flight the wings are broken off at a suture near the base and discarded. The wing-stubs serve to identify dealated first form adults. This is the caste that originates a colony by pairing and laying eggs

2 : The second form males and females are less pigmented, with rudimentary or nonfunctional wing-pads or wings (brachypterous), eyes and reproductive organs are smaller than in the first form. These are supplementary or substitutional kings and queens.

3 : The third form adults are scarcely pigmented, entirely wingless (apterous) the eyes are vestigial and the mature reproductive organs smaller than in the second form.

The Sterile Castes.

4 & 5 : The workers are wingless, unpigmented "white ants", with the eyes small or absent but the head broad and pigmented. They are of both sexes but the reproductive organs are not functional.

6, 7 & 8 : The soldiers are wingless with a large strengthened and pigmented head, usually with large or variously modified mandibles. The eyes are vestigial and both sexes are sterile. [fig. 151].

Origin of the castes.

The castes of termites appear (according to the views of one school) to be determined in the fertilised egg or embryo by intrinsic factors and are not the result of selective nutrition, presence of protozoan parasites, tending by older workers, etc. Two forms of nymphs differing in the size of brain, eyes and reproductive organs hatch from the eggs, which give rise to the reproductive castes, and to the soldier and worker castes. Castes cannot be determined or changed by external means. Each of the adult sexual forms (1–3) can on occasion reproduce itself and the forms below it in rank, but not those above it. The reproductive processes of the termites are thus very complicated; furthermore there is no difference due to fertilisation or nonfertilisation as in bees (Apidae) because all termite eggs are fertilised.

The social functions of the castes.

The social functions of the various termite castes correspond to those of analogous castes among the ants (Formicidae).

1 : At certain times of the year under favourable conditions of humidity and temperature the sexual forms reach maturity. As winged males and females they remain in the nest until a swarming flight takes place. The kings and queens leave the nest in large numbers and spread over great distances, workers and soldiers usually throng the exit-holes at the time of the swarms. Congregation takes place at numerous points and the individuals associate in couples. The wings are broken off at the basal suture, and the paired king and queen begin to found a new nest. A small hole is dug in the soil and eggs are laid. The first hatched castes are workers and a few soldiers and are cared for by the royal pair until fully developed —a period of several months. The subsequent termite colony is the offspring of the one royal pair.

In most genera the queen in later life becomes changed in bodily form owing to the distension of the abdomen [fig. 152]. The inter-segmental skin of the abdomen stretches as a result of the enormous growth of the ovaries and the fat-body until she attains a length of 2 to 4 inches and 20,000 times the volume of one of her workers. Copulation is frequent and the laying of eggs is machine-like in its regularity; it has been estimated that about 30,000 eggs a day are laid, which means 100 million eggs if

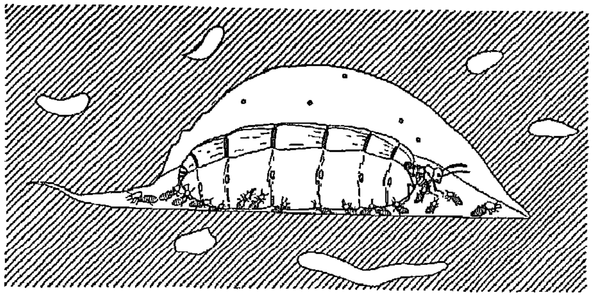


Fig. 152. Royal chamber of Cyclotermes, in section, showing and old queen termite attended by workers and soldiers.

her life-time lasts ten years. The king increases slightly in size after repeated copulation. The royal pair are usually housed in a special royal chamber in the middle of the termite nest.

2 & 3 : The second and third forms of adults are usually considered as substitution forms or reserves that may take the place of the true king and queen if casualities occur, or if part of the colony gets cut off from the main body. These supplementary reproductives play an important part in the economy of the termite colony and make it potentially immortal. A supplementary queen is very effective as a reproductive and may lay eggs more rapidly than does a primary queen. They are more important among the damp-wood and subterranean termites than among the dry-wood termites.

4 & 5 : The function of the workers is mainly that of tending the eggs and young nymphs, of feeding and cleaning the other castes especially the royalties, and constructing and repairing the nest. They appear to control the social system of the colony. The Kalotermitidae have no special worker caste and the immature stages of other castes perform the functions of the worker.

6, 7 & 8 : Soldiers may be of two very different types. Most species have mandibulate forms with large jaws, [fig. 151, Nos. 1–6], and these serve in the defence of the colony, protecting the workers when labouring on the nest or when foraging; in other genera of the Termitidae (Eutermes group) the head of the *nasuti* forms is retortshaped or produced anteriorly in the form of a long tubular snout with the opening of a gland at its tip [fig. 151, No. 8]. These *nasuti* forms are able to squirt a protective sticky fluid from the tip of the snout; mandibulate soldiers such as *Coptotermes* eject a similar secretion from a pore situated in front of the head [fig. 151, No. 4]. Soldiers also work as scavengers, and in *Cryptotermes* have the front of the head truncate so as to function as a shovel or ram. The high polymorphism of soldiers makes

the caste useful for taxonomic purposes. Holmgren recognises at least 12 different stages of soldiers.

The food of termites.

The feeding-habits of the termites are very complicated. In addition to water six varieties of food are consumed of which the principal one is cellulose. Termites are a dominant group in their habitat because of their ability to use wood-cellulose as food. Cellulose is a carbohydrate rich in energy and constantly produced by plants in great abundance, but very few kinds of animals are able to digest it. Termites thus have an abundant food-supply and very few competitors. The hind-intestine of the majority of wood-eating termites contains a rich fauna and flora comprising Protozoa (flagellates, amoebae, spirochaetes) and bacteria and fungi. Some of the protozoa contain enzymes that are believed to effect the digestion of cellulose. At any rate if the termites are deprived of the protozoa they cannot live. All the cellulose eaten is not neccessarily digested, as faeces contains appreciable proportions of unaltered cellulose. The lignin of wood has no food-value and is excreted unaffected by the digestive juices; it may form two-thirds of the excrement of a termite feeding on a wood with a high lignin-content. Those species of termites which obtain their food from other sources than cellulose alone, such as humus, the organic matter in soil, and fungi, usually have no intestinal protozoa.

They have developed an elaborate system of mutual feeding with saliva, with regurgitated partially digested food (stomodaeal food) and with ejected faeces (proctodaeal food). The latter is repeatedly eaten in periods of food-shortage until no nutritive value is left and is then discarded. All castes exude fatty substances through the thin abdominal skin which are licked up by other members of the colony; that of the queen is particularly relished by the workers. They also clean each other's bodies of encumbering dust, wood-particles and moulds. Cast skins and dead bodies as well as sickly individuals are eaten by the soldiers. It is because of this habit of feeding on faeces, skin exudates, moults and dead bodies that poisonous substances, which have been carried into the colony by a few individuals, are rapidly spread throughout the entire colony—a characteristic that is utilised in control measures.

Lichens, algae and grasses are eaten by foraging termites. Fungi form important items of food in some of the most highly evolved forms.

F u n g i: The fungus-growing termites belong to the most highly specialised Isoptera, the genera *Termes*, *Cyclotermes* and *Microtermes*. The cultivation of fungus is carried on in special chambers in the nest. Each chamber contains one or more fungus-gardens which are sponge-like bodies varying from 1 to 6

inches in diameter, made of the vegetable matter forming termite-excreta. On the surface of this medium the fungus grows in the form of mycelium bearing globular food-bodies. The food-fungus is a species of *Volvaria* with which is always found a mushroom-forming *Xylaria*; the latter is possibly a weed that the termites are unable to extirpate. Infection takes place automatically, since the workers prepare the combs from fungus-infected wood and the conidia pass through their intestines undigested.

A large number of species of fungi (other than those cultivated in gardens) are associated with termites; they are species of fungi that commonly grow in decaying wood and include saprophytes as well as lignin-dissolving and cellulose-dissolving forms. Elements of the fungi occur in the faecal pellets of termites and on the walls of their burrows and are evidently eaten by them, but the full significance of the food-value or disintegrating function of such fungi is not yet known. Kofoid points out that wood-destroying fungi thrive independently of termites in wood in forests and dwellings, but termites do not occur in wood without direct and continuous relations with fungi. Termites benefit from the presence of fungi in their cellulose diet and the fungi are favoured by their association with termites. The fungus spores and hyphae are carried about on the bodies and in the intestines of termites and thus reach depths of the wood where otherwise they might not arrive. Termites produce and maintain in their burrows a moist atmosphere rich in carbon dioxide which favours the growth of fungi. Termites are associated with dry rot and decay of wood not by mere accident, but because they cannot carry on their normal life without intimate and sustained association with fungi. It is possible that the protective and preventive effects of control measures used against termites result from their more direct action on the fungi than by their direct action on the termites themselves.

Habitat groups of termites.

Termites can be grouped according to the habitats in which they are found and their habits from a biotic and economic aspect. The habitats of these groups are of considerable importance in determining the methods that can be adopted to prevent damage by termites.

WOOD DWELLERS
- (a) Damp-wood termites
- (b) Dry-wood termites

GROUND DWELLERS
- (c) Subterranean termites
- (d) Mound-building termites
- (e) Carton-nest-building termites

WOOD DWELLERS

The wood-dwelling termites belong largely to the family Kalotermitidae. The colony is confined entirely to wood and is started

by a colonising pair which enters the wood above ground at the time of swarming.

(*a*) The damp-wood termites require a constant high amount of moisture in the wood in which they live such as in found in dead or decaying logs and stumps of trees in regions with a moist cool climate. *Archotermopsis wroughtoni* is an example. Some species of *Kalotermes* and *Neotermes*, which live inside the wood of living trees, may be considered to be damp-wood termites.

(*b*) The dry-wood termites can maintain their colonies in dry, sound, seasoned wood; some species are also called powder-post termites because they eject fine wood-dust-like pellets from their excavations and the soldiers have short, truncated heads suitable for blocking the entrances of the tunnels. (compare with the Bostrychidae). The genera *Cryptotermes*, *Kalotermes* and *Neotermes* (Kalotermitidae) are representatives.

GROUND DWELLERS

The ground-dwelling termites comprise tbe families Rhinotermitidae and Termitidae. The colony is always partly in the ground and in connection with it and is started by a colonising pair which enters the earth or wood in the earth.

(*c*) The subterranean termites build covered runways from the nest through the ground or over exposed surfaces to reach wood elsewhere. They do not build mounds or exposed nests but live in the soil or in wood in diffuse chambers sometimes containing semi-carton sponge-like fillings. This group includes the genera *Coptotermes* and *Heterotermes* (Rhinotermitidae).

(*d*) The mound-building termites are familiar by reason of their white-ant-hills, which are conspicuous turreted and buttressed mounds of cemented earth in or below which they cultivate fungus-gardens and construct a special royal chamber. They enter buildings through woodwork in contact with the ground. Representative genera are *Cyclotermes*, *Hypotermes*, *Macrotermes*, *Microtermes* and *Termes* (Termitidae).

(*e*) The carton-nest-building termites construct a cellular nest of carton (a compound of faecal matter and woody fragments and and earth) which may be located in the ground or in wood or on branches of trees. Connection with the ground is maintained by means of covered runways. Several species are foraging and grass-eating termites. Representative genera are *Hospitalitermes*, *Microcerotermes*, *Nasutitermes* and *Trinervitermes* (Termitidae).

Classification of termite nests.

The various types of nests may be classified by the following characters which may be variously combined in different types :—

(a) Diffuse or concentrated in plan
(b) Subterranean or non-subterranean in situation
(c) Built of earth, of carton, or of earth and carton mixed, or without special materials.

(i) **Diffuse or irregular nests**, which are characteristic of the

more primitive termites, are not built to any constant pattern. They consist only of irregular galleries and chambers hollowed out in the substance in which the community of termites is living; this may be underground in the soil or in the wood of logs, trees, etc.

In the *ground-dwelling species* the nest is not permanent and, at the best, is an assortment of small rounded chambers connected by tunnels; there is no indication of its presence above ground and it is difficult to trace by digging. Subterranean nests do not occur in very wet regions or where the sub-soil water-level is high.

Irregular nests are made by *wood-dwelling species* in logs, fallen trees and stumps; they may also occur in the dead or rotten wood of living trees, and very rarely in healthy living tissues. The wood is removed to form a porous or honey-combed labyrinth, the walls of which are formed of very thin layers of wood left intact and strengthened by a deposit of excrement, or cement, or amorphous earth-fillings. Some species of Kalotermitidae fill the empty cavities with pellets of partly digested excreted wood, and this often falling outside reveals the presence of termites as surely as their peculiar boring-dust betrays coleopterous larvae; e.g., the very primitive species, *Archotermopsis wroughtoni*, in logs of coniferous wood; *Kalotermes domesticus* in building timber (Kalotermitidae); *Coptotermes heimi* and *Heterotermes indicola* in timber (Rhinotermitidae).

(ii) **Concentrated nests** are clearly marked off from their environment by a definite system in the arrangement of their chambers and tunnels, or by a difference in the material of the nest and that of its immediate neighbourhood. Both earth and wood specially prepared are used as building materials in the construction of nests. The substances are swallowed by the workers and, after mixture with secretions, are either regurgitated or passed out as excrement; this semi-plastic material is employed for building walls or plastering surfaces. In addition particles of soil or wood are used after simple mixture with saliva. On drying, these building materials, especially the saliva impregnated earth, set almost as hard as cement. When deposited in thin sheets and struts the material is termed "carton",—*earth-carton* being mainly cemented clay and *wood-carton* being semi-digested wood particles or cellulose, and lignin.

Nests of the concentrated plan may be entirely subterranean or mainly above ground in the form of mounds, or in hollows in the trunks of standing trees, or attached externally to the branches.

S u b t e r r a n e a n n e s t s: A typical subterranean concentrated nest consists of a single large chamber incompletely divided by partitions rising from the walls and containing a fungus-garden; other smaller peripheral fungus-gardens are used as nurseries and communal rooms; and several large main passages and numerous finer tunnels, e.g., *Termes feae* (Termitidae) [fig. 153].

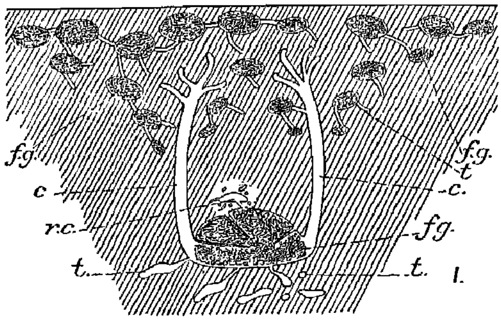


Fig. 153. Section through a termite nest of the concentrated subterranean type.

$c.$ = main shaft or 'chimney'. $r\,c.$ = royal chamber.
$f.g.$ = fungus gardens. $t.$ = communicating tunnel.

W o o d - c a r t o n n e s t s : Nests built in hollow trees have the cavity filled with a foliaceous mass of wood-carton full of large cavities and are often marked externally by irregularly lobed pendant masses of carton of coarser consistency. There is no special royal chamber as the king and queen live within the carton-comb at the centre and the eggs and young nymphs occupy the outer zones; e.g., *Hospitalitermes monoceros* (Termitidae).

Conspicuous spherical nests of cellular wood-carton are built by some species attached to the branches or placed in the fork of trees. These nests have a more or less definite concentric or stratified arrangement of the cells and chambers, with a central royal chamber. Such nests, of the size of a foot-ball and larger, resemble superficially the nests of some arboreal ants and wasps and are known in some countries as "nigger-heads". The termites make their way along the bark of the trunk to the ground by narrow run-ways roofed in with mud, e g., *Nasutitermes indicola* and *N. lacustris* (Termitidae). Compact spherical carton-nests of similar construction are also built underground by species of *Hospitalitermes* and *Microcerotermes heimi* (Termitidae).

M o u n d n e s t s : A termite mound or termitarium or white ant hill takes the most fantastic forms, e.g., conical, columnar, turreted, domed, mushroom-shaped, etc. and in Africa and Australia reaches a height of 20 feet and covers so much ground that the laying of a road or railway track has necessitated a cutting through the mound. In parts of India mounds interfere seriously with the upkeep of earth roads.

The mound-building species belong to the higher groups of termites and are represented in India chiefly by species of *Cyclotermes*, *Hypotermes* and *Termes*. In the mound-builders there are three castes—the sexual forms, the workers and the soldiers. Each colony originates from one sexual pair, the king and queen,

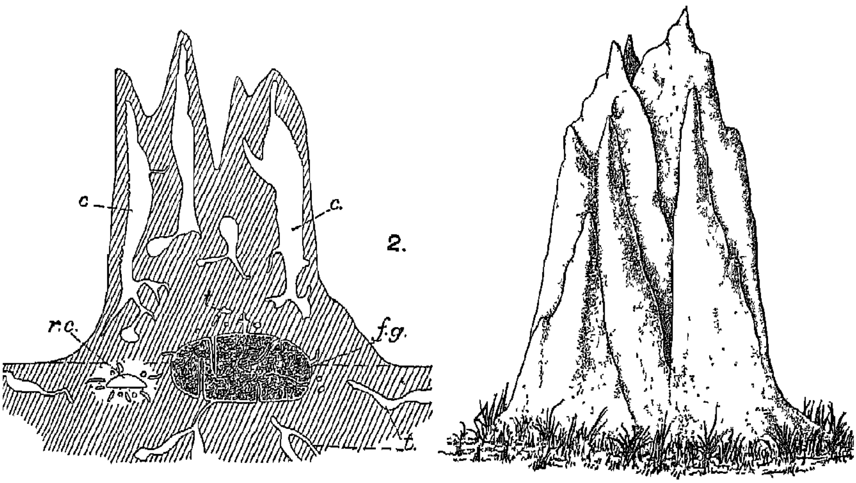


Fig. 154. Termite mound—the nest of a species, Cyclotermes obesus, building a unilocular mound.

Right—perspective view. Left—diagrammatic section through same.

c. = main shaft or 'chimney'.	*r.c.* = royal chamber.
f.g. = fungus-garden.	*t.* = communicating tunnel.

and its subsequent growth is dependent on this royal pair or on the queen alone. Unlike other termites the colonies of *Cyclotermes* do not contain supplementary queens able to take the place of the founder-mother in an emergency. Consequently if the mound be destroyed and the royal pair removed the life of the colony is limited. The mound may be rebuilt by the workers, but it outlasts only their span of life, which may not extend to nine months. A community of which the queen lives on may persist for ten or twelve years.

The simplest structures visible above ground, to which the term mound can be applied, take the form of low, broad, conical heaps; between these and elaborate buttressed erections various intermediate types exist, which characterise different species or different stages in the growth of a community of one species.

Unilocular mound: A conspicuous mound found throughout the Peninsula and sub-Himalayan tract is that of *Cyclotermes obesus*. In the subspecies *C. obesus oculatus* [fig. 154] the mound has the form of a more or less cylindrical central mass flanked by massive narrow buttresses rising vertically from a broadened base and ending in a sharp peak or pinnacles at the summit of the mound often 5 to 7 feet above ground-level. The cross-section of the mound resembles in outline that taken through a buttressed tree near its base a yard or more across. The walls

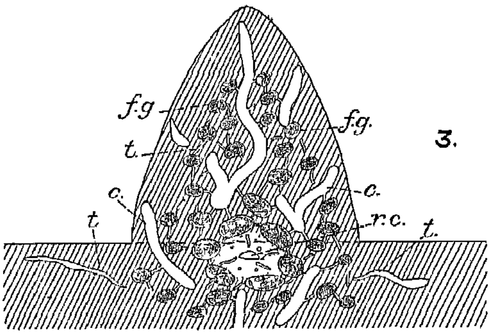


Fig. 155. Section through a termite mound—the nest of a species, Cyclotermes redemanni, building a multilocular mound.
c. = main shaft or 'chimney'. *r.c.* = royal chamber,
f.g. = fungus garden. *t.* = communicating tunnel.

of the buttresses are of solid cemented earth and of moderate thickness, without any external openings and the buttresses within are hollow and empty; but the central core is a more compact mass, mainly solid, with several vertical galleries or chimneys also empty. Small tunnels allow access of termites to various parts of the mound above ground, but the regularly inhabited part of the nest is at and below ground-level. Here is a single large chamber incompletely divided by earthen partitions descending from the roof and rising from the floor like stalactites and stalagmites in a limestone cave; sometimes this chamber is nearly divided into a upper and lower storey by a horizontal floor. The whole internal space is filled with the fungus-garden of the colony, and is tenanted largely by young nymphs and other castes of the community. Access to the fungus-garden chamber is obtained through numerous tunnels of small diameter.

To one side of or below the garden chamber is the royal cell in a block of rather more compactly cemented earth. The cell is oval in plan with a low domed roof and a flat floor; and in it the queen and king are emprisoned. Fine tunnels communicate with it and allow the workers to approach with food or to remove the eggs; the adjacent passages are also used as guard-chambers in which soldiers are always on duty.

The remaining subterranean portion of the nest comprises a few communal chambers and passages of different sizes some of which lead away from the mound in various directions towards the foraging grounds of the colony.

Multilocular mound: A mound of another type occurring in South India and Ceylon is that of *Cyclotermes redemanni*. [fig. 155]. Its form is that of a cone ending in a sharp peak, or a rounded domed top (in weathered or old mounds), with fairly

regular rough walls, non-buttressed, but sometimes bearing subsidiary conical pinnacles and furrowed with rain-channels. The height may be over six feet. The main mass of the mound is a solid, extremely hard, cemented earth in which are numerous, domed, flat-floored chambers containing fungus-gardens. Unlike the unilocular type this kind of termitarium is chambered throughout from just below the summit to a considerable distance below ground-level. The chambers may number a hundred and are connected by numerous tunnels sometimes a centimetre in diameter, but generally only large enough to permit the passage of two or three termites together. Similar tunnels communicate with large open shafts or chimneys, which run more or less vertically from the top and sides through the mound towards its base where they peter out.

The royal chamber is built near the centre of the mound at about ground-level, oval and low domed in a zone of small intricate tunnels as in other species of mound-builders.

The structure and composition of the mound of mound-building termites are intended to maintain the humidity of the nest at a constant nearly saturated degree independently of the weather conditions outside. The walls of the innermost chambers adsorb more moisture than the middle layers and the outer walls adsorb much less than the former. The differential adsorption values of the layers in the walls of the mound provide a buffer mechanism which compensates for variations in the rates of production and of loss of moisture. The moisture produced by the metabolism of the termites of the colony is retained and not lost at the surface of the mound by diffusion or evaporation. Rainfall and soil-moisture is not absorbed in excess in the form of free water within the chambers of the mound.

T h e c o n s t r u c t i o n o f a m o u n d: The community of a mound-building termite is long-lived and during its life the mound may alter much in extent and shape due to normal extension as also to repairs following on accidents, such as erosion by rain and destruction by men and animals. Construction above ground does not begin until the colony of workers and soldiers derived from the original royal pair is fairly numerous. New mounds are built in the rainy season usually at night but also on overcast damp days. A crater-shaped hole is opened in the ground and "round the hole a rampart is rapidly built by the workers, each of which carries up in its mouth a minute pellet of earth, which it lays in position and cements with its saliva. As the rampart grows in height it contracts gradually in circumference and assumes a conical form; finally a roof is added, but if the roof be not complete before conditions become unfavourable for work, the orifice is left open above but blocked up at the base of the crater until next evening, to prevent the entry of enemies or rain. The wall and roof are at first very thin, consisting of a single layer of the pellets brought up from underground by the workers. It is, moreover, porous, small interstices being left in a fairly regular arrangement between the pellets. Behind each pore a soldier is on guard...

The process of construction can be observed most easily by breaking

down a part of the mound in dull, damp weather. The workers near the breach at first retreat but the soldiers remain, snapping their jaws. Then, in a few minutes, a crowd of workers and soldiers wells up from below. All is apparent confusion, but imperceptibly the soldiers take up their position round the aperture, each with its jaws pointing outwards and its soft body under cover. Each of the workers carries in its jaws a pellet of earth, which it deposits in exactly the right place, secreting a little drop of saliva upon it as it does so. Thus the new wall rises rapidly as a fragile shell, and as it rises, more and more soldiers come on guard, one behind every little pore it contains. Should the new roof have too wide a span to be constructed without support, a pillar rises simultaneously from below to meet it, built by other workers. The whole work is perfectly coordinated, but there is no apparent reason how or why the little blind, hurrying workers produce between them a perfect whole. Once the outer shell is complete, or even before its higher parts are finished, workers begin to strengthen and thicken it from within, depositing more earthen pellets inside the first outer layer. The soldiers still remain on guard, however, and the wall is built round them, leaving each a little cavity with an opening on both the outer and inner surface". (Annandale).

When repairs become necessary in dry weather the wall is built thicker from the beginning. When the mound has to be enlarged or altered the old wall is eaten away from within and a new one is constructed. As a multilocular mound is enlarged the internal arrangement of chambers and fungus-gardens may be modified and new ones constructed in the upper zones.

Economic importance of termites.

The economic importance of the termites is twofold. Their activities are both extremely beneficial and extremely injurious to man. The subject has recently been reviewed by each interested government in the British Commonwealth of Nations and reported to the Council of the Imperial Agricultural Bureaux.

BENEFITS: In the subtropical and tropical parts of India they perform the important functions of the earthworms and humus-inhabiting organisms of moist temperate regions, but on a vaster scale. "Since they are so very numerous and feed almost exclusively on dead vegetable substances they conspire with the bacteria, high temperature and humidity to accelerate the disintegration of all the lifeless plant-matter and to convert it into humus which can be at once utilized by the growing vegetation. The termites are therefore important agents in assisting the growth and renewal of the great rain forests of the Amazon, the Congo and the East Indies. But even in the dry savannas of South America and open forests of Australia they hasten the dissolution ro the dead grasses and other herbaceous plants as well as that of the sparse bushes and trees." (Wheeler). In the higher mountain regions of India above about 4,000 feet elevation and in swampy of waterlogged land termites are of negligible importance as makers of soil.

INJURIES: Since the principal food of some of the termite castes is cellulose, they directly injure and destroy both living and dead vegetation and the woodwork of buildings as well as the

material stored therein. Termites *are among the few forest* insects that are able to live in and on both decayed and living plant-tissue. "While not dominant insects like the ants which *over-run* the tropics, termites by their hidden or subterranean activities silently, secretly and ceaselessly work their insidious damage and are able to *under-run* some tropical countries." (Snyder).

The role of the Isoptera in relation to forestry and forest products may be considered under three heads, viz., 1. Damage to the living plant, 2. Damage to timber in the open, 3. Damage to buildings and their contents.

1. **Damage to living plants:** Termites injure living plants *originally by attack from outside, but may continue the destruction* of living tissues by working (a) from outside or (b) from within.

(*a*) In the first case, damage may occur (i) underground by hollowing out or severing or partly removing the bark of roots, and (ii) above ground by removing the dead bark of the trunk under the shelter of narrow runways or broad spaces roofed in with earth, and by extending natural cracks, abrasions or other wounds in the bark, so exposing the living cambium and wood, which after desiccation and partial decay is further destroyed in later seasons.

The roots of trees are attacked as a rule when the plant is quite young, 1 to 3 years old, particularly in nurseries and artificially *sown or planted areas. In such localities the soil is* abnormally enriched with leaf-mould, litter, green manure, etc., or is full of fragments of wood and bark and sawdust derived from the clearing of the forest. On this material the local ground-dwelling termites subsist for a time and after exhausting it turn their attention to the woody roots of living plants. Liability to attack is usually greater in the dry season, as the young trees are then less resistant and rootlets injured in planting and hoeing die back, but also the great need of termites for moisture may force them to obtain it from succulent roots. Damage of this nature occurs to artificial regeneration of, e.g., *Shorea robusta*, *Tamarix articulata*, *Tectona grandis*, *Terminalia myriocarpa*. Some trees like *Eucalyptus* spp. are particularly susceptible. The species of termites responsible are those belonging to the subterranean and mound-building groups.

Above ground termites may establish themselves under cover of mud runways in natural cracks in the bark of quick growing trees; the dry dead tissues are eaten and the removal of these causes the dying-back of the exposed living tissues which are likewise eaten, so that the crack progressively enlarges and no callus is formed. Injury of this type has been observed in quick growing coppice of *Shorea robusta*.

(*b*) In the second case, termites penetrate a living tree by way of a dead branch or stub or through the bark at a wound

or weakly resistant area in the root or in the bole and branches, and establish themselves in a cavity in the heartwood, which is gradually enlarged until big enough to contain a subsidiary nest with its fillings and chambers of carton or earth. Continued excavation may eventually result in the death of some of the roots or the whole tree in addition to ruination of the timber. Damage of this type has been observed in rubber trees by, e.g., *Coptotermes curvignathus*, or in tea bushes by *Kalotermes militaris* and others, and in teak in Java by *Kalotermes tectonae*. But practically nothing is known of the habits of this group of termites in natural forests in India.

Some species of *Nasutitermes*, foraging termites which collect grass and lichen, nest in hollow trunks or on branches but are not destructive to timber.

2. **Damage to timber in the open:** Under natural conditions in the forest fallen trees, branches, twigs, leaves, etc., are eaten away by termites—the soft woods in one or two seasons, and the hard woods relatively slowly. Exposed logs and stumps of relatively resistant timbers may last at least 20 years before disappearing. Timber under conversion, poles, fencing, bridges, railway sleepers, etc. are similarly injured. The responsible termites are species of *Coptotermes*, *Cyclotermes*, *Heterotermes*, *Microtermes*, *Neotermes*, and *Termes*.

3. **Damage to buildings and their contents:** Timber used in the consrtuction of buildings, bridges and articles of furniture, shelves, boxes, books, papers, fabrics, cloth, leather, etc., in contact with floors or walls especially in damp or dark places, are attacked by termites from tunnels made in the ground or masonry. Termites can enter the superstructure of buildings because somewhere there is untreated wood in contact with the ground or with earth or with inferior mortar in the walls. In destroying wood or other edible material the termites work in concealment eating away from the inside and leaving the exterior untouched; the cavities are often filled with earth or deposits of excrement both as a protection and to prevent the structures collapsing. Thus the damage may be extensive before it is detected.

The most important species infesting buildings are *Kalotermes domesticus*, *Coptotermes heimi*, *Heterotermes indicola*, *Termes feae*, *T. obscuriceps*, and *Cyclotermes redemanni*. The problem of protecting buildings in India concerns almost exclusively the subterranean termites; elsewhere the drywood termites are of equal or greater importance.

LITERATURE ON TERMITES:

(Excluding the literature dealing specially with control measures, for which see Part Two).

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KALOTERMITIDAE

THE KALOTERMITIDAE are wood-inhabiting termites, founding and maintaining their colonies inside wood which is often sound and relatively dry so that they need not have access to the ground and moisture. Several species are pests in buildings and form the group known as "dry-wood termites"; others live in cavities in the heartwood of living trees, and others in wood with a high amount of moisture, viz., "damp-wood termites".

Archotermopsis wroughtoni is the sole representative of its genus and one of the most primitive living termites and a representative of the damp-wood dwellers. It is found at elevations of 4,000′ to 9,000′ in the Himalayas (Kashmir to Kumaon) and makes its nest in fallen trees and stumps of conifers, *Abies pindrow*, *Cedrus deodara*, *Pinus excelsa* and *P. longifolia*, the wood of

which is already decayed and is constantly moist; green timber and living trees are not attacked. The colony comprises relatively few indviduals and is composed of the royal pair, winged males and females, soldiers and worker-like forms and nymphs; there is no true worker caste. "The soldiers rank among the largest known and are chiefly remarkable in that they exhibit well-defined external secondary sexual characters, a feature which has become lost in almost all other Termites". (Imms). [fig. 151, No. 1, showing the deeply pigmented subparallel-sided head, with the large powerful teeth on the mandibles]. The nest is not a definite concentrated structure but consists of irregular chambers and large tunnels running longitudinally with the grain of the wood or cutting across the annual rings obliquely. No earth or carton-fillings are used but crevices are sometimes stopped up with masticated wood or excrement consolidated with saliva. Swarming occurs at irregular intervals during the monsoon, June to August.

Desneux J., 1906, *Journ. Bomb. Nat. Hist. Soc.*, XVII, p. 293, figs.

Cryptotermes, Neotermes and **Kalotermes.** These genera differ from those of the higher termites in having no true worker caste; the work of the community is carried out by the nymphs, which develop into reproductives, either winged or wingless. The soldier has a large quadrangular head, flattened or excavated in front, which modification is of use in defence as the soldier stops up an enrance-hole with its head. [fig. 151, No 2]. The fillings in the tunnels are composed of dry oval pellets of excrement or the same mixed with saliva. All are true wood-dwelling termites, particularly of dry wood in buildings, not nesting below ground. *Cryptotermes* can exist without the great amount of moisture required by subterranean termites; some *Neotermes* require a minimum amount of moisture and some *Kalotermes* live inside the wood of living trees.

Cryptotermes bengalensis occurs in wood of *Heritiera fomes* and *Erythrina indica.*

Cryptotermes domesticus is a wood-eating termite making its nest in dryish seasoned wood above ground-level, and frequently occurs as an injurious pest in the woodwork of buildings (in Ceylon and in Malaya). Colonies are initially formed by a pair of winged adults which have been able to establish themselves in a suitable place in the timber or closely in contact with it. Narrow tunnels are excavated by the nymphs of the new colony in which there are no true workers. Parts of the tunnels are filled with wood-dust or compressed pellets of excrement (which consists largely of wood) either dry and loose, or slightly consolidated with saliva. No carton-fillings or fungus-combs are constructed. The soldier has the fore parts of its rectangular head truncate so that it is useful for plugging up the entrance to tunnels or pushing out the excreta; the mandibles have several coarse teeth.

Glyptotermes ceylonicus occurs in the wood of *Artocarpus integrifolia*.

Hodotermes macrocephalus inhabits sandy soil in the Punjab and Sind plains. It is reported as injurious to young transplants, particularly of *Prosopis*, in irrigated plantations; it is a foraging species feeding largely on grass.

The genus *Hodotermes* is primitive but has developed a worker caste and, in consequence of this higher social evolution, is sometimes classified as a separate family, the HODOTERMITIDAE.

Neotermes assmuthi. Like most members of the genus, *N. assmuthi* is a primary wood-eating termite, not cultivating fungus; it nests inside hard timber lying on the ground and rarely appears in the woodwork of buildings. The nest consists of a diffuse excavation of cavities and tunnels without any coating of excrement or carton. There is no true worker caste. The soldier has a large parallel-sided head, arched and somewhat flattened in front with strong mandibles, each bearing several teeth.

Neotermes bosei occurs in dead branchwood (*Ficus* spp., *Salix* sp.).

Glyptotermes dilatatus, Neotermes greeni and **Neotermes militaris.**

These three species make nests in the heartwood of living tea bushes in Ceylon and in other living trees, *Aleurites fordii*, *Casuarina equisetifolia*, *Cedrela toona*, and *Crotolaria anagyroides*. The winged adults enter dead snags or knots or other wounds in trees, and establish themselves in a small cavity which is enlarged as the young of the colony increase and grow up. Tea bushes are infested only through the contact of roots of healthy and attacked bushes. The nest has no definite system of tunnels and chambers; the heartwood is excavated quite irregularly and the cavities are partly filled with earth. The colony is self-contained and consists of a small number of workers, soldiers [fig. 151, No. 2], and winged and wingless adults. In the case of *Neotermes militaris*, the final winged stage takes over 7 years to develop and it is estimated that a colony may inhabit a single isolated tea bush for over 15 years. *Glyptotermes dilatatus* takes at least four years to produce winged adults. The tree shows very little evidence externally of being attacked and for a time its vigour is not affected. The tunnels are in the heartwood and living tissue is not attacked.

King C. B. R., 1937, *Tea Quart.*, x, pp. 195–205, pls. 4, Neotermes militaris (in Ceylon).
Corbett G. H. and Miller N.C.E., 1936, *Sci. Ser. Dept. Agr. S.S. & F.M.S.*, No. 17, pp. 12, pls. 4.

Neotermes gardneri lives in the dead branchwood of living trees, e.g., mango.

Kalotermes tectonae is a serious pest of living teak trees in Java, at present unknown in India, Burma or Ceylon. Plantation trees 20–30 years old are badly attacked but liability extends

from 8 to 80 years. The nest is installed in the heartwood which is eaten away in long vertical galleries. Outside the bark becomes swollen and fissured and develops into a canker something like that of *Dihammus cervinus* (Cerambycidae).

RHINOTERMITIDAE.

THE RHINOTERMITIDAE include species of termites that are all subterranean in habit, nesting in the ground but invading buildings.

Coptotermes. This genus comprises termites feeding exclusively on wood and not cultivating fungi; the nest is below ground-level or in logs or in the fairly damp woodwork of buildings. The soldiers defend themselves by means of a white milky fluid secreted in a large gland extending from the head into the abdomen; the secretion is expelled from an opening in the front of the head and hardens on exposure into a gummy or rubbery solid. [fig. 151, No. 4].

Coptotermes ceylonicus occurs from Ceylon to Indo-China and is one of the more important termites affecting buildings, destroying beams, rafters, planking of walls and floors, door and window-frames as also stacked timber, packing-cases, and logs in contact with the ground. It works in brick walls in the mortar-joints and is able to penetrate the hardest lime-mortar and even into the interior of bricks by enlarging natural pores. The cavities hollowed out in wood are often built up with a spongy mass of wood-carton (which resembles the fungus-beds of the fungus-growers, but has a quite different function). The nest may be formed in the soil, whence timber and buildings are invaded through the walls or under cover of mud tunnels, or the woodwork may be infested directly by termites arriving in the winged stage. This termite also attacks living tea bushes in Ceylon and south India, and other trees, entering through decayed or wounded places in the roots and also through similar places on the stem and broken branches. [fig. 151, No. 4].

Jepson F. P., 1929, *Dept. Agr.*, *Ceylon*, Bull. No. 85, p. 8, pl. ii, fig. 3, pl. iv, v, vii.

Coptotermes curvignathus, The Rubber Termite.

This termite occurs in north India and Burma and is able to attack living trees and establish itself in the heartwood, which is gradually destroyed and the tree is killed. It is a serious pest in rubber plantations (*Hevea*) in the Federated Malay States, Java, Sumatra, etc., and at one time a prize of £5,000 was offered by the Planters' Association to the inventor of a cheap and effective remedy, easy of application and certain of result. The prize was not awarded.

The main nest of *curvignathus* is made in dead timber, in logs and stumps, partially or wholly buried in the soil, and never in living trees. In the hollowed out cavity a labyrinthine mass of

wood-carton is constructed which houses the queen and the nurseries of the eggs and young. From the breeding-centre smooth-walled runways ramify in different directions broadening out in places to form large flat spaces from which branch-tunnels diverge; the larger of these lead to subsidiary nests inside stumps and logs or fallen trees, or to living trees. Subsidiary nests contain only workers and soldiers. The attack on living trees takes place in the roots or above ground,—in the latter case the trunk is wholly encased in a thick crust of earth, the bark is eaten away and, through weak places, scars, knots, etc., the termites penetrate to the heartwood of the tree, which is largely excavated and filled with wood-carton combs. It also occurs in woodwork in buildings. Among the trees attacked by the Rubber Termite are *Albizzia procera*, *Artocarpus blumei*, *Bombax malabaricum*, *Canarium commune*, *Cocos nucifera*, *Eriodendron anfractuosum*, *Ficus elastica*, *Hevea brasiliensis*, *Mangifera indica*, *Oroxylon indicum*, *Salix* spp., *Sapium baccatum*, *Semecarpus anacardium*, *Shorea robusta* and spp.

Pratt H. C., 1909, *Dept. Agr., F. M. S.*, Bull. Nos. 1 and 3 (recorded as *Termes gestroi*).

Caresche L., 1937, *Compt. Rend. Trav. Inst. Rech. Agron. For., Indochine*, 2, pp. 195-212, pl. 6, Le termite destructeur de l'hevea et du kapokier.

Coptotermes heimi is essentially a wood-eating species and does not cultivate fungus; it is one of the most important termites infesting buildings throughout India. Its mode of attack on timber is similar to that of *Heterotermes indicola*; the harder parts of the wood such as knots, duramen of differentiated annual rings, heartwood, etc., are ordinarily not destroyed and the softer parts are removed irregularly but tunnels may be made through hard wood where required. In certain timbers such as *Cedrela toona* this selective feeding may convert the wood into long, straw-like, loose fibres. The outer surfaces of constructional timber and logs are left intact. The cavities are filled with a tough mottled brown to bluish-black deposit formed in an irregular spongy or stringy network resembling superficially fungus-comb. The cells are narrowly oval with their long axis in the same direction as that of the wood-fibres; their walls consist of very thin flakes of wood strengthened with a covering of excrement and rarely of earth; smooth surfaces are covered with a coarse grained coating of excrement. Narrow covered runways of excrement are constructed in order to pass over exposed surfaces.

In buildings it damages the woodwork and also causes leakage of electric current by destroying the insulation and earthing up the wiring in conduits and joint-boxes. Several instances of damage to railway carriage stock are recorded (G.I.P.Ry.); the termites nested in sheltered parts of the carriage body such as the gap between the steel panels and the inside lining boards, whence runways were made to the softwoods used for backing of cushions

and ceilings.

From nests in stumps or logs or in the soil it makes runways on the bark of living trees and on wooden structures in contact with soil. It is one of the species occuring in graveyard testing-stations, e.g., at Lahore. *C. heimi* swarms at sunset during the dry season and especially in January to March. The soldier has an oval, dark brownish-red head with slightly curved mandibles.

Assmuth J., 1913, *Journ. Bomb. Nat. Hist. Soc.*, XXII, 2, pl. iii (feeding-patterns in deal and yarra).

Annandale N., 1923, *Rec. Ind. Mus.*, XXV, pp. 233-251, pl. v, figs. 5, 5 *a*.

Coptotermes parvulus makes a simple nest of small extent underground whence it tunnels into logs on the ground and ascends the trunks of trees in the bark in galleries covered in with earth. **C. travians** occurs in wood stored in timber yards. It also works on the surface under galleries of earth.

Heterotermes ceylonicus is a pest in the woodwork of buildings. It nests in the soil without the formation of a mound.

Heterotermes indicola. Throughout the greater part of the Indian Peninsula and upto 7,000 feet in the Himalayas this is one of the most injurious wood-destroying termites in buildings. It lives in fallen trees and stumps in the forests. Wood forms the staple diet in preference to anything else. When working in wood the softer parts are removed first and the harder parts such knots, duramen in differentiated annual rings and the outer surfaces, are left intact till the last. The cavities are filled with a greyish carton, mainly excrement, in sheet or ribbon-like deposits connected by transverse partitions and pillars. The deposit is also used to cover smooth surfaces such as glass, cement, etc. and to make narrow linear covered ways from the underground nests to distant timber. *H. indicola* swarms in the morning during the early monsoon showers. The soldiers are of two sizes and have the head elongate parallel-sided, with the mandibles very slightly curved, the left with a few rudimentary teeth at the base [fig. 151, No. 3].

Among the identified timbers eaten by this species are *Cedrela toona*, *Flacourtia ramontchi*, *Pinus longifolia*, *Quercus* (imported), *Shorea robusta*, *Tectona grandis*.

Assmuth S., 1913, *Journ. Bomb. Nat. Hist. Soc.*, XXII, pl. 2, figs. 1-3 (feeding-patterns in deal and teak).

TERMITIDAE

THE great majority of termites belong to this family. All species live in the ground but exhibit a wide range of habits as regards food and the construction of the nest. Unlike the other families the TERMITIDAE do not possess any Protozoa in the intestine. Possibly because of the absence of intestinal Protozoa the Termitidae do not generally feed on sound wood but utilize decayed or weathered wood, fungus, dead vegetable matter, grass, leaf mould, etc.

The genera *Eutermes*, *Hospitalitermes*, *Nasutitermes* and *Trinervitermes* comprise rather specialised termites, that are not primarily wood-eaters and do not cultivate a fungus but subsist mainly on grass, lichens, algae, etc., which they collect by making foraging expeditions from the nest; some species march in exposed columns without the protection of earth-covered runways. The soldiers are distinguished by reduced mandibles and a long conical or tubular process from the front of the head and are hence known as *nasuti* [fig. 151, No. 8]; from a gland within the head a viscous fluid is excreted at the tip of the projection. The nests are concentrated cellular structures of wood-carton built underground or in hollow trees or exposed on branches.

The genera *Cyclotermes*, *Hypotermes* and *Termes* comprise mainly species that cultivate fungus in special chambers in a nest constructed on a concentrated plan either subterranean or in mounds, i.e., the so-called white-ant-hills. Most are occasional wood-eaters but some species are pests of timber inside and outside buildings. The soldiers have well developed mandibles with one or more teeth [fig. 151, No. 5].

Amitermes belli has been found in the roots of *Cistanche tubulosa*.

Cyclotermes bangalorensis occurs in the dryer parts of Madras, Central India, Punjab and United Provinces and is a mound-building, fungus-cultivating species that occasionally attacks wood in contact with soil. Its mound, when fully developed, is a large structure with walls rising in fluted buttresses straight up from a broader base and terminating in separate massive pointed peaks 6 to 8 feet above ground-level. It resembles that of the commoner *Cyclotermes obesus* [fig. 154]. The fungus-gardens are cultivated in a large chamber below ground, which is divided incompletely by partitions; the fungus-combs are intricately convoluted spongy masses. The royal chamber is centrally situated at one to two feet below ground-level; its very thick walls have a few perforations and may be surrounded by small egg and nursery-cells (Assmuth). The secretion ejected by the soldiers stains the human skin slightly.

It occurs in the timber-testing graveyard at the F. R. I., Dehra Dun, affecting numerous species of timbers including *Acacia arabica*, *A. catechu*, *Bombax malabaricum*, *Cedrus deodara*, *Dalbergia sissoo*, and *Shorea robusta*.

Cyclotermes brunneus is a mound-building fungus-cultivating species of which the mound rises 3–4 feet above ground-level, and is crowned with a number of rounded domes or cupolas. The walls are rather friable and porous, not solid like those of *C. bangalorensis* and *C. obesus*. The royal chamber is more or less central at ground-level. The soldiers eject a milky fluid, which stains the human skin with a brown spot that does not disappear for several days (Assmuth).

Cyclotermes obesus.

This species [fig. 151, No. 5] is a common mound-building termite throughout India cultivating fungus and working mainly on woody surface-debris such as twigs, bark-fragments, dry leaves and grasses, cowdung, etc., and occasionally damaging fuel-wood and timber lying on the ground. It is also considered to be a pest of agricultural crops. To reach such food-supplies tunnels are carried underground whence the termites come up to the surface and work under temporary earthen shelters. The mounds constructed by *C. obesus* vary considerably in shape, and some of the more definite shapes are characteristic of subspecies. The building of a mound is described on pages 535, 536.

In the form *obesus oculatus* typical large mounds [fig. 154] may be 6 feet high and 3 feet in diameter with more or less vertical walls and cylindrical form, which is broken up by frequent laterally compressed buttresses that broaden out at their bases and narrow at their tops into separate little peaks. These buttresses and a narrow central chimney are hollow. There are numerous vertical galleries and short transverse ones, but they do not lead to any external openings. Almost the whole of the basal part of the mound is occupied by a large chamber partly above and partly below ground-level, which contains the single fungus-garden of the community. This garden-chamber is incompletely divided by partitions, that hang from the roof, or rise from the floor, like stalactities and stalagmites in a cave. The fungus comb nearly fills the chamber, being practically a cast of it except that its outer surface is covered with irregular grooves and small circular holes leading into internal cavities [fig. 154].

The royal chamber is flat with a low domed roof and is situated a little to one side of the fungus-garden at about ground-level. [fig. 152]. Numerous narrow complicated galleries communicate with it.

The form *obesus typicus* (according to Annandale) constructs several small conical mounds 1 to 3 feet high in a group often at the base of a tree or shrub. These mounds may be contiguous or a few feet apart, sometimes in a straight line, sometimes scattered irregularly, but communicating below ground-level. In its internal structure the nest of this form differs from that of *obesus oculatus* in the absence of buttresses and of galleries in the upper part of the mound. The cultivation of fungus is not confined to a single chamber but is carried on in many (20 or 30) small separate gardens. Each garden-chamber is nearly spherical with smooth polished walls; they are distributed in the mound above ground, often a few inches below the peak, and in the ground below the mounds; they communicate by narrow passage-ways to each other and to the vertical shafts running through the mound. The fungus-combs are not quite spherical, slightly convex above and flat or concave below or sometimes mushroom-shaped.

The royal chamber is situated underground at the base of a mound; in an old group of mounds, that have coalesced, this chamber may occupy the centre above ground. *Cyclotermes obesus* swarms at the break of the monsoon (June) beginning at dusk and flying throughout the night.

Assmuth J., 1912, *Journ. Bomb. Nat. Hist. Soc.*, XXI, pp. 775-793. XXII, pp. 102-114, 375.

Annandale N., 1923, *Rec. Ind. Mus.*, XXV, ii, pp. 233-251, figs. 1, 2. pls. v, vi.
— 1925, *Journ. Bomb. Nat. Hist. Soc.*, XXX, pp. 25-35.

Cyclotermes redemanni. In Ceylon this species is one of the commonest mound-builders and is also commonly found damaging the woodwork of buildings.

The mound [fig. 155] is a massive conical termitarium ending in a peak 6 or 7 feet above ground; old mounds may have the summit rounded off into a dome and the sides furrowed with rain-channels. From openings on the top or sides big chimney-like shafts penetrate through the nest to its base where they ramify and end. The outer wall of the mound is thick and solid; within it are numerous oval garden chambers united to one another by small canals and also to the chimney-shafts. These fungus-gardens are also constructed in the extension of the nest below ground and may exceed a hundred in number. As with the majority of mound-builders the fungus-comb of *redemanni* has a general resemblance to a coarse bath-sponge; it is of a more foliaceous structure with fewer surface pores than in *Hypotermes obscuriceps*, and much less uniformly convoluted than in *Termes ceylonicus.* In these fungus-gardens the eggs and all stages of workers and soldiers congregate. Situated centrally below ground-level is a single thick-walled chamber containing the royal pair; its floor is flat and horizontal and the roof is a low oval dome. Canals of fine diameter permit the access of workers and the removal of the eggs. From the base of the nest galleries run out underground to distant food-supplies. Sometimes the royal chamber is situated in the upper part of the mound above ground and may contain 2 queens (Mukerji).

Mukerji D. and Raichoudhury S., 1941, *Proc. 28th. Ind. Sci. Congr.*, Abstracts p. 204. Morphological changes following growth and differentiation of the various phases of the common mound-building termite, Terms redemanni Wasm.

Cyclotermes wallonensis builds a mound of a few feet elevation with chimneys opening at the surface in wide mouths. The royal cell is below ground and surrounded by nursery chambers.

It is reported as injurious to *Casuarina equisetifolia* in plantations, and to buildings in irrigated plantations of *Dalbergia sissoo.*

Globitermes birmanicus is found in dead stumps and logs including the sapwood of *Tectona grandis.*

Hospitalitermes birmanicus occurs on teak saplings.

Hospitalitermes monoceros. The Black Termite.

This species occurs in Ceylon, where it is known as the Black Termite. Both the worker and the soldier are of an unusually dark colour; the head of the latter is pear-shaped, drawn out in front into a conical tube [see fig. 151, No. 8]; the worker has the eyes well-developed and long legs. It nests in hollow branches or trunks of trees and fills the cavity with a single, large structure of carton. The comb or carton is composed of thin, contorted, blackish-brown layers united into a coarse foliaceous mass full of large cavities. The substance of the layers consists of brown amorphous masses of excrement with fragments of the epidermis of various plants, a few pieces of black fungus-hyphae and a few fungus-spores and numerous acicular and cubical crystals; the same mixture is found in the stomachs of workers and soldiers (Petch). There is no special royal chamber as the queen and king live within the comb at the centre, and eggs and young nymphs occupy the outer zones.

Connected with the nest cavity on the outside of the branch or trunk of the tree is a black pendent mass of irregular shape but usually extending in several separate projecting lobes. It is penetrated by galleries and cavities like the inner nest, but is built of coarse pellets which adhere lightly and are not worked up into a cement. When dry it falls to pieces readily and, unless in a sheltered position, is washed away when rain falls. This external structure is continually being rebuilt and serves for the disposal of the waste products of the colony, but is apparently also used for the assembly of the winged adults before flight.

H. monoceros does not cultivate a food-fungus and does not eat wood. Lichens form its staple food, especially the crustaceous species of loose texture with a powdery surface. Foliaceous lichens with a tough smooth cortex are avoided. Green algae and some moulds are also eaten. In order to collect food the termites make foraging expeditions at night in organised processions of several hundred thousand individuals. "A black ribbon, about three quarters of an inch in width, extends from the nest to the feeding ground, often for a distance of about fifty yards. The individuals in the procession are all workers, usually six abreast, but sometimes ten, while the soldiers stand at intervals at right angles to the moving mass, ready to ward off the attacks of enemies". (Petch). The route passes over open ground, roads, walls, trees, etc., and is marked by minute black streaks of excrement, so that after a few journeys it becomes a permanent black streak. Ants, especially *Oecophylla smaragdina* (Formicidae), are the chief enemies to which the procession is exposed; birds do not attack the black termite. The soldiers are able to frighten away the ants but do not apparently eject a defensive secretion. Their additional function is to select the route and regulate the march of the workers. After loading up with small balls of

lichen the workers return to the nest, so that the procession eventually consists of an outgoing stream and a laden homegoing stream side by side. The last of the column often does not reach the nest until some hours after dawn.

Hypotermes obscuriceps is a mound-building, fungus-cultivating species. In Ceylon it infests buildings and is probably more frequently met with than the other species of termites damaging timber in houses. Entrance is effected not only through the floors, but also through cracks in the lime-mortar of walls, and in concrete, particularly through settlement-joints.

Its mound is a broad-based conical edifice pointed or domed at the top and reaching a height of 5 feet, very similar to that of *Cyclotermes redemanni*. The interior of the mound above ground contains many chambers, in which fungus-gardens are established, communicating by tunnels of small diameter. The whole mound is penetrated by several wide galleries or chimneys, opening externally which are considered to act as aeration shafts. At ground-level is the domed, flat-bottomed, royal chamber with thick walls permeated by minute communication tunnels.

The soldier has an oval head with slightly curved jaws, the left of which has a few teeth in the basal half.

In Indo-China, according to Bathellier, the nest of this species is entirely subterranean. The fungus-gardens are cultivated in one large chamber about 2 feet below ground-level and in many small chambers above the former and just below ground-level. The fungus-comb is brownish-yellow, very friable and usually very moist. Below the large garden is the royal chamber, situated in a block of hard cemented earth, which is perforated by a few canals of small diameter. From the main collection of chambers galleries run out in various directions to rise to the surface in order to reach the vegetable debris, leaves, branches, etc., which form the subsidiary diet of the colony. Under certain conditions unfavourable to living plants, e.g., drought, overcrowding, etc., they may be attacked by this termite.

Hypotermes xenotermitis occurs on *Morus indica* and *Tectona grandis* in Burma.

Macrotermes serrulatus occurs in Burma in the northern plains and in oak and pine forests. It nests in the soil making a small mound and cultivating fungus-gardens; it swarms as early as May after rain.

Microcerotermes annandalei is a wood-eating species not cultivating fungus; its colonies live in the damp wood of logs. The nest is similar to that of *Coptotermes heimi* and it is possible that the deserted nests of *heimi* are occupied by *annandalei*. It swarms at the beginning of the monsoon [fig. 151, No. 6].

Annandale N., 1923, *Rec. Ind. Mus.*, xxv, pp. 233-251.

Microcerotermes bugnioni. This minute species feeds on dead and rotting wood. Its nest is made of wood-carton like that

of a *Eutermes* and is placed low down on a tree or at soil-level.

Microcerotermes heimi occurs very rarely in buildings, living chiefly in timber logs and stumps in the forest and nesting underground or in dead bamboo clumps, etc. The spherical nest is made of wood-carton in a uniformly honey-combed or stratified mass of small chambers communicating by small pores through the partition-walls, which are just large enough to allow the passage of the termites. The outer surface is covered with a thin crust of earth applied in small pellets. The royal chamber is situated somewhat below the centre of the nest and is surrounded by a zone of chambers used as nurseries. Special chambers are constructed to accommodate substitution queens when they are produced (Assmuth).

The head of the soldier is yellow, rectangular, parallel-sided with a small protuberance near the base of each antenna; the mandibles are slightly curved and their inner margins are irregularly serrate [see fig. 151, No. 6].

Microtermes incertoides. A very small species making an underground nest consisting of a zone of small chambers containing fungus-gardens lying around a large royal chamber and some communal cells, all connected by fine bored branching tunnels. The nest may also be constructed in the wall of a mound-builder. The walls of the chambers and the tunnels are smoothly polished and rounded off. The fungus-comb is in the form of an irregularly spongy mass of yellowish semi-digested wood-tissue. The soldiers are not numerous; a whitish viscous liquid is ejected in defence.

Microtermes obesi lives in small communities underground or in the walls of the mound of a mound-building termite, such as *Cyclotermes obesus*, and in the nest-area of burrowing termites such as *Termes feae*. Its nest consists of numerous small rounded chambers connected by narrow passages; the chambers contain masses of eggs and young nymphs or fungus-gardens. The fungus-combs of *M. obesi* are of a simple type and consist usually of masses of pale, yellow, globular pellets of excrement, piled together rather loosely in a flattish cake or in a rather irregular cellular mass with reticulate ridges on the upper surface.

From the nest this termite makes foraging expeditions to timber, logs, dead wood and bamboos lying on the ground in which superficial shallow cavities and tunnels extending along the grain are eaten. It does not occur in buildings. Sometimes growing plants, such as sugarcane, wheat, garden flowers, are attacked. The soldier is very small with a yellow oval pubescent head and slender mandibles bent at the tip; a transparent coagulating fluid is secreted.

Annandale N , 1923, *Rec. Ind. Mus.*, xxv, pp. 233-251, pl. v, figs. 4, 49, (anandi).
Assmuth J., 1915, *Journ. Bomb. Nat. Hist. Soc.*, xxiii, pp. 691, 692.

Microtermes pallidus attacks tea bushes in Malaya boring into the stems where they have died back and sometimes eating the

stems of recently planted seedlings. (Corbett and Miller, 1936).

Microtermes unicolor has been found attacking the aerial roots of *Ficus bengalensis*.

Nasutitermes indicola builds globular wood carton nests around a branch, or in a hollow in a tree; from the nest to the ground black earth covered runways are made on the bark of the trunk.

Nasutitermes lacustris. This foraging termite builds a globular wood-carton nest, one to two feet in diameter, on a branch or fork high up on or in the hollow of a tree. The royal chamber is subcentral and surrounded by a zone of chambers containing eggs and nymphs, around which is a zone of large elongated cells followed by a zone of smaller cells and a thin superficial protective layer. Earth-covered runways on the bark of the trunk descend to the ground.

Termes ceylonicus attacks timber in contact with the ground and is one of the important species infesting buildings in Ceylon. Its nest is normally underground but occasionally its colonies are found inhabiting the mounds of *Hypotermes obscuriceps* and *Cyclotermes redemanni*, in which it constructs its own chambers and fungus-gardens. The fungus-combs of *ceylonicus* differ from those of the other two species mentioned in being more uniformly convoluted and of a harder consistency.

Termes feae is one of the most important termites infesting buildings in India and Burma. It lives in large communities in complex nests entirely underground [fig. 153]; in the excavation of the underground chambers large quantities of earth are thrown out in a shapeless mass often piled up against the roots of trees or filling up hollow tree-trunks. In these cavities are often constructed irregular, oblong, vertical chambers with thick rough walls formed of pellets of excavated earth; the colour of these fillings is that of the surrounding soil; they break easily when dry. No true mound is formed.

When attacking exposed timber this species usually works from the outer surface inwards unlike most of the other common house-infesting termites. A broad protective coating of earthen particles is constructed over the surface of the wood where it is exposed to the light; underneath this shelter the wood is wholly removed in irregularly shaped depressions, which are later filled up with earth. When working in houses the cracks in brickwork, masonry, and settlement joints, etc., are used as runways roofed in with a layer of earth. It is recorded as killing *Eucalyptus* seedlings planted out in bamboo baskets. It swarms at the break of the monsoon at night-fall and flies throughout the night.

Microtermes obesi is frequently found nesting in the area occupied by *T. feae*.

Assmuth J., 1913, *Journ. Bomb. Nat. Hist. Soc.*, XXII, 2, pl. iv, figs. 2, 3 (feeding-patterns in deal and Ficus wood).
Annandale N., 1923, *Rec. Ind. Mus.*, XXV, p. 244.

Termes horni makes purely subterranean nests whence it reaches distant timber by means of underground tunnels. It works on the trunks of living trees under cover of broad earthen shelters and eats the outer dead bark, but not as a rule exposing or damaging the living tissues. *T. horni* rarely establishes itself in buildings.

Termes malabaricus does not build a mound; it lives in the soil and cultivates a fungus-garden and swarms at the beginning of the monsoon.

Termes parvidens. Among the identified timbers attacked by this species are *Duabanga sonneratioides*, *Melanorrhoea glabra*, *Pinus longifolia*, *Shorea robusta*, *Sterculia villosa*. Found in the plains and up to 6,000 ft. in the Himalayas. Its nest is subterranean and irregular (without a mound). Swarming occurs in March evenings from small holes in the ground.

Trinervitermes biformis

The commonest foraging termite in India is *Trinervitermes biformis*. Its workers are pale yellow, long-legged, but without eyes; its soldiers are of two sizes about one tenth and one fifth of an inch long with pear-shaped heads terminating in front in a slender tube [see fig. 151, No. 8].

The nest is entirely subterranean, frequently situated below large stones and rocks, a few inches to a foot below ground-level and consists of a ramification of passages with black stained walls, "a reticulated system of galleries and chambers, their width being equal to about that of a lead pencil........The patch of ground is literally honeycombed with the network" (Hingston). The earth derived from the excavation of the galleries is thrown out in little heaps but no definite mound is constructed above ground. Some of the chambers serve as nurseries for the young nymphs; others for the storage of food which consists mainly of grass.

T. biformis makes foraging expeditions for the purpose of collecting grass, setting out from the nest in thousands, a little before sunset. The processions consist of workers marching to the harvesting-ground in an orderly column. Along the route and scattered around the working-area the soldiers take up positions from which they can defend the workers against marauding ants, e.g., *Lobopelta* and other enemies. "When alarmed, the foragers set about retirement; the stream of labourers pours back to the nest. But the soldiers remain out until all have disappeared; then the warriors themselves withdraw, forming, as it were, a rear guard to the mass". In attack and defence the soldier shoots from the frontal tube a clear sticky fluid which hardens on exposure in glutinous coils.

Sometimes short low earth-covered tunnels are built on the surface of the soil in order to approach grass in safety. The grass is cut off at the tips by workers that have climbed the blades, and the pieces are carried back one by one to the nest.

Hingston R. W. G., 1928, *Journ. Bomb. Nat. Hist. Soc.*, xxxii, pp. 717-725 (Eutermes biformis).

Trinervitermes heimi is a foraging termite sending out *processions to collect grass. Its nest is subterranean and diffuse.*

LEPIDOPTERA

THE ORDER LEPIDOPTERA

MOTHS and Butterflies constitute the second largest Order of insects in the world with about 120,000 described species, i.e., an order about half the size of the Coleoptera; a satisfactory census has not yet been made of the number of species in the Indian region.

Imago: The imaginal form in the LEPIDOPTERA [fig. 157] is very uniform in structure and there is no difficulty in recognising a moth or butterfly at sight, although the range in size is from about 1/8th of an inch to giants with a wing-span of nearly 10 inches. The most characteristic features are the large compound eyes; the long simple or pectinate or ciliate antennae; the tube-like highly specialised proboscis, usually coiled spirally between the conspicuous labial palps; the 2 pairs of wings covered with coloured scales which conceal the weak venation, strengthen the wing-membrane aerodynamically and enable colouration to reach its highest degree of specialisation among insects. The colour of the minute flattened and broadened scale is due to pigment and to light-interference caused by the irregularities of its surface; a scale may have longitudinal ridges or striae at a density of 35,000 to the inch. When the moth is at rest its wings may be held roofwise, their posterior margins meeting along the medio-dorsal line of the abdomen (e.g., Hepialidae) or horizontally, either completely spread out (Geometridae) or with the forewings forming a triangle over the hindwings (Noctuidae), or vertically upwards with the upper surfaces in contact (butterflies). In flight the fore and hind wings are held together by a finger-like process on the forewing which passes under the costa of the hindwing; or a stiff bristle on the anterior margin at the base of the hindwing which engages in a set of thick bristles on the underside of the forewings, or by simple overlapping pressure. Some female moths have reduced or vestigial wings and consequently are able to crawl only and not fly.

The efficient flying organs of moths and butterflies enable them to move swiftly and far. Some Hawk and Swift Moths are remarkable among insects for their speed in flight; some butterflies cover trans-continental distances in their seasonal migrations and safely traverse broad oceans. Local migrations or dispersal of large populations of moths and butterflies are important causes of epidemic outbreaks of defoliators.

Oviposition: Eggs are either (a) laid singly or in masses fixed to the food-plants by means of a sticky secretion, or (b)

scattered freely while flying, or (c) inserted into suitable protected places by means of a tubular ovipositor.

Larva: [fig. 156] The larva is a caterpillar, elongate and generally cylindrical, the body soft-skinned and either naked in appearance (most Noctuidae), or clothed in various degrees with erect bristles or hairs, which are arranged on tubercles or warts singly (e.g., Pieridae) or in clusters or in dense tufts (e.g., Arctiidae, Lasiocampidae, Lymantriidae); some forms are provided with spines (e.g., Sphingidae) or fleshy processes (e.g., Nymphalidae). The colours and surface-patterns of caterpillars show a wide range; in some species they vary from instar to instar. In the mouth of caterpillar, the labium-hypopharynx carries a median process, the spinneret, from which silk is spun into a fine thread and used in making a cocoon for pupation; the silk is secreted as a copious fluid from the large silk glands within the body. The thorax bears 3 pairs of short legs. On the 10 segments of the abdomen there are normally 5 pairs of sucker-feet (claspers or prolegs) which are short, fleshy, more or less conical processes, flattened at the apex and provided with a series of hooklets or crochets. The typical caterpillar has sucker-feet on segments 3, 4, 5, 6 and 10; in some species of Noctuidae (semi-loopers) sucker-feet are present only on segments 5, 6 and 10; in the Geometridae, the true loopers, only those on segments 6 and 10 are fully developed; in some leaf-mining and tunnelling caterpillars the prolegs and also the thoracic legs may be much reduced in size or totally absent. Some Limacodidae resemble slugs or gelatine lozenges.

Pupation: The number of the larval instars is normally 4. It may pupate in an exposed position or in shelter as in a cell, tunnel, cocoon, etc, which may be made of soil-particles, wood or bark-fragments, silk, larval hairs, etc. The pupa or chrysalis is (a) incomplete, i.e., the appendages are completely sheathed but partially free and more than 3 of the abdominal segments are moveable (3–6 or 4–6). The incomplete pupa is therefore mobile and able to travel in its cocoon or tunnel; or (b) obtect, i.e., a hard smooth rounded skin with the appendages completely fixed, only abdominal segments 5 and 6 moveable; the obtect pupa is therefore not mobile but remains on the spot in which the larva pupates attached to a pad of silk threads by means of a group of hooks (cremaster) at the top of the last abdominal segment.

Food: The feeding-habits of the imagines, the moths and butterflies, are very uniform: liquid containing soluble or suspended organic matter and salts, sweet, sour and putrid, is sucked up through the proboscis. Larval feeding-habits on the other hand are determined by their chewing mouth-parts. There are larval lepidopterous representatives in almost every type of herbivorous

feeding-habit, in living and in dead plants but there are very few among the putrivorous larvae. None of the larval forms are true sapsuckers, and, although the imaginal forms suck up exposed liquids, it is very unusual for a moth to pierce plant-tissues deliberately to obtain sap. Carnivorous larvae of Lepidoptera are not numerous and are restricted to predaceous types. The following synopsis of larval feeding-habits gives examples of families in which the chief types occur.

Synopsis of larval feeding-habits of Lepidoptera

HERBIVOROUS

Eaters of buds and flowers, i.e., many families

Eaters of seeds and fruits, e.g., Blastobasidae, Carposinidae, Eucosmidae, Pyralidae

Shoot-borers, e.g., Blastobasidae, Gelechiidae, Oecophoridae, Pyralidae

Bole and branchwood borers, e.g., Cossidae, Hepialidae, Indarbelidae, Tineidae

Dead-bark-borers, e.g., Tineidae

Leaf-eaters, i.e., almost all families

Leaf-rollers, e.g., Eucosmidae, Pyralidae, Tortricidae

Leaf-miners, i.e., many microlepidopterous families

Soil-dwellers, cutworms, e.g., Noctuidae, Tineidae

CARNIVOROUS

Predators. Blastobasidae, Epiplemidae, Epipyropidae, Lycaenidae, Noctuidae, Tineidae.

Alternative food-plants: Alternative food-plants are now known for many species of herbivorous Lepidoptera in India; some species include a wide range of plants in their diet while others restrict their choice to allied genera or families of trees. Many polyphagous species are of economic importance as factors in the natural control of defoliators that are pests: this is because they act as alternative hosts of the parasites of the pests. Several species previously known only as pests of agricultural crops have latterly been found wild on shrubs and underwood trees in forests.

Life-cycle: The life-cycle varies from annual to about 15 per annum, the shortest taking about 3 weeks; prolongation of the annual life-cycle to two years rarely occurs (e.g., in the larval stage of *Xyleutes*, Cossidae). Species of defoliators with an annual life-cycle usually take a series of years for a gradation, that is, to multiply to epidemic numbers and to decline to normal; multicycled species, on the other hand, usually complete a gradation within 12 months and the population-density returns to base-level every year. Those species of defoliators that have several generations a year are much influenced by climatic factors and the number of complete consecutive cycles in a year varies with localities. Some types of borers change their feeding-habits

and environment in successive generations, e.g., *Hypsipyla robusta* (Pyralidae) in the flower, fruit and shoot of *Cedrela toona*, and *Pammene theristis* (Eucosmidae) in the seed, seedling-root and coppice-shoot of *Shorea robusta*. Emergence-periods for the majority of forest-inhabiting Lepidoptera are rarely well-defined over an extended area except for the first post-hibernation or post-aestivation broods and for species with an annual generation.

Butterflies: India is justly described as the most ideal country in the world for a butterfly collector; the wide range of its climatic and environmental conditions has produced a most diverse fauna: 1,443 species are recorded from the Indian region. Consequently it is not surprising that the Rhopalocera as a group have been more thoroughly collected, field-studied, systematised and documented than any other group of insects. In India they have attracted all sorts of persons and personages from schoolboys in the hills to Governors and Viceroys: and not a few forest officers have found butterfly-collecting to be a hobby that claimed them throughout their service. There are more injurious species in the group than is generally realised and there is still scope for intensive studies of the ecology of such species, including their migratory habits, some records of which have been assembled by Williams, 1938. Numerous reference books are available (see below).

LITERATURE ON BUTTERFLIES:

For a complete bibliography consult Talbot, 1939, *Fauna of British India*. There are numerous contributions on butterflies to Indian Journals in the form of catalogues, faunal lists, descriptions of adults and early stages, bionomics, etc., by Betham, Davidson, Doherty, Ellis, Elwes, Evans, Fergusson, Ghosh, Gough, Hannyngton, Home, Mackinnon, Manders, de Niceville, Ollenbach, Peile, Rhe-Philipe, South, Tytler, Watson, Wood-Mason, Yates, etc.

Antram C B., 1924, *Butterflies of India*, pp. 226, figs. 412.

Bell T. R. D., 1909-1927, *Journ. Bomb. Nat. Hist. Soc.*, (in numerous serial parts with figs. and coloured plates), The common butterflies of the plains of India.

Bingham C T., 1905, *Fauna Brit. Ind.*, Butterflies, I, pp. 511, figs., pls. 10, Nymphalidae, Nemeobiidae.

— 1907, *tit. cit.*, II, pp. 480, figs., pls. 10, Papilionidae, Pieridae, Lycaenidae.

Corbett A. S. and Pendlebury H. M., 1934, *Butterflies of the Malay Peninsula*.

Evans W. H., 1927, 1st ed., 1932, 2nd ed., *The identification of Indian butterflies* (reprint from *Journ. Bomb. Nat. Hist. Soc.*, 1922-1926) pp. 302, pls. XXXII.

Moore F., 1881, *The Lepidoptera of Ceylon*, I.

Moore F. and Swinhoe C., 1890-1913, *Lepidoptera Indica*, I-X.

Ormiston W., 1924, *The butterflies of Ceylon*.

Peile H. D., 1937, *A guide to collecting butterflies in India*, pls. XXV.

Talbot G., 1939, *Fauna Brit. Ind.*, Butterflies, I, 2nd ed., pp. 600, figs., 3 pls., Papilionidae, Pieridae.

Watson E. Y., 1894, *Journ. Bomb. Nat. Hist. Soc.*, Classification of the Hesperiidae.

Williams C. B., 1938, *Journ. Bomb. Nat. Hist. Soc.*, XL, pp. 439-457, pl. 1, figs. 4, Records of migration of butterflies in India.

Young L. C. H., 1905-1907, *Journ. Bomb. Nat. Hist. Soc.*, The common butterflies of the plains of India (continued by T. R. D. Bell).

Economic importance: Pests of forests classified in the Lepidoptera are numerous but are entirely pests of the living tree; none are injurious to felled timber and very few destroy forest products other than wood. In the Indian region the notorious defoliators are those of teak, shisham and deodar and the most injurious borers are the mahogany shoot-borer and the beehole borer.

Classification: For the classification of the Lepidoptera the arrangement proposed by W. T. M. Forbes (1923, *Lepidoptera of New York*) is adopted with modifications for the Microlepidoptera following T. B. Fletcher, 1921–1933. Keys to the divisions and families are given by Hampson and Fletcher.

LITERATURE ON LEPIDOPTERA:

(Excluding literature dealing mainly with *Butterflies* which is listed on p. 556).

Bell T. R. D. and Scott F. B., 1937, *Fauna Brit. Ind.*, Moths, v., Sphingidae, pp. 537, figs., pls. 15.

Chatterjee N. C., 1935, *Ind. For. Rec.*, Ent., I, No. 10, pp. 185-204, Entomological investigations on the spike disease of sandal (2), Lepidoptera.

Fletcher T. B., 1926, *Agr. Res. Inst. Pusa*, Bull. 162, pp. 73-83, Tentative keys to the Orders and families of Indian insects.

— 1921, *Mem. Dept. Agr. Ind.*, Ent., VI, Nos. 1-9, Life histories of Indian Insects, Microlepidoptera, 217-10, pls. LXVIII.

— 1932, *Imp. Counc. Agr. Res., Sci. Mon.* No. 2, pp. 58, pls, XXXV. 1933, *tit. cit.*, No. 4, pp. 85, pls. LXXVII, Life-histories of Indian Microlepidoptera, Second series.

— 1929, *Mem. Dept. Agr. Ind.* XI, A list of the generic names used for Microlepidoptera.

— 1925-1931, *Catalogue Ind. Ins.*, 1925, Part 7, Lasiocampidae; 1925, Part 8, Amatidae (Syntomidae); 1925, Part 9, Zygaenidae; 1928, Part 16, Cosmopterygidae; 1928, Part 17, Yponomeutidae; 1931, Part 20, Alucidae (Pterophoridae); 1931, Part 22, Phalaonidae and Chlidanotidae.

Forbes W. T. M., 1923, *Cornell Univ. Agr. Expt. Sta.*, Mem. 68, The Lepidoptera of New York and neighboring states, pp. 729 figs. 439.

Gardner J. C. M., 1938, *Ind. For. Rec.*, Ent., III, No. 10, Immature stages of Indian Lepidoptera (1) Lymantriidae—1941, *tit. cit.*, VI, No. 8, ibid (2) Noctuidae.

Hampson G. F., 1893, *Fauna Brit. Ind.*, Moths I, pp. 527, figs. , Saturniidae to Hypsidae, 23 families.

— 1894. *tit. cit.*, II, pp. 609, figs., Arctiidae, Agaristidae, Noctuidae, 3 families.

— 1895, *tit. cit.*, III, pp. 546, figs., Noctuidae to Geometridae, 5 families.

— 1896, *tit. cit.*, IV, pp. 594, figs., Pyralidae, addenda to 30 families.

Lefroy H. M., 1909, *Indian insect life.*

Moore F., 1881-1887, *The Lepidoptera of Ceylon*, I-III.

Moore F. and Swinhoe C. 1890-1913, *Lepidoptera Indica*, I-X.

Sevastopulo D. G., 1939-1940, *Journ. Bomb. Nat. Hist. Soc.*, XL, XLI, parts I-V, The early stages of Indian Lepidoptera.

— 1940, *tit. cit.*, XLI, pp. 817-827, On the food-plants of Indian Bombyces.

Synopsis of the families of the Order LEPIDOPTERA

Suborder **JUGATAE**	
	Hepialidae
Suborder **FRENATAE**	
ZYGAENOIDEA	**Limacodidae**
	Zygaenidae
	Epipyropidae
TINEOIDEA	**Tineidae**
	Psychidae
	Lyonetiidae
	Plutellidae
	Epermeniidae
	Lithocolletidae
GELECHIOIDEA	**Gelechiidae**
	Cosmopterygidae
	Oecophoridae
	Xyloryctidae
	Blastobasidae
YPONOMEUTOIDEA	**Yponomeutidae**
	Glyphipterygidae
	Heliodinidae
TORTRICOIDEA	**Tortricidae**
	Eucosmidae
	Carposinidae
	Cossidae
PYRALOIDEA	**Thyrididae**
	Hyblaeidae
	Pyralidae
	Pterophoridae
URANIOIDEA	**Epiplemidae**
	Uraniidae
SATURNIOIDEA	**Saturniidae**
BOMBYCOIDEA	**Bombycidae**
	Eupterotidae
	Lasiocampidae
GEOMETROIDEA	**Geometridae**
SPHINGIDOIDEA	**Sphingidae**
NOCTUOIDEA	**Notodontidae**

Hypsidae
Lymantriidae
Noctuidae
Arctiidae
Syntomidae

Suborder **RHOPALOCERA**

HESPEROIDEA **Hesperiidae**
PAPILIONOIDEA **Papilionidae**
Pieridae
Lycaenidae
Nymphalidae

NOTE: The above synopsis omits the names of numerous families and some of the superfamily series used by Forbes; it includes all the family names discussed in this book and places them in the serial order adopted by Forbes and, for the Microlepidoptera, by Fletcher. The spelling and synonomy of some names differ for various reasons from the forms used by these two authorities.

AGARISTIDAE see NOCTUIDAE
ARBELIDAE see INDARBELIDAE

ARCTIIDAE

SMALL to moderately large moths [fig. 157, No. 28] brightly coloured and patterned, many species laying eggs prolifically in clusters; hairy caterpillars [fig 156, No. 4] with the long hairs in tufts and the crotchets of the sucker-feet heteroideous without pubescent gibbosities. Some species, e.g., *Amsacta albistriga*, *Diacrisia obliqua*, increase periodically and produce large armies of migrating hairy caterpilars which are polyphagous and destructive to crops and vegetation generally. For control measures see Part Two.

Hampson G. H., 1894, *Fauna Brit. Ind.*, Moths, II, pp. 1-147, figs. 97.

Amsacta lactinea is a general feeder on agricultural plants and also on *Cassia tora*, *Clerodendron infortunatum*, *Menispermum glabrum* and *Vitex negundo*. Eggs are sometimes laid on the leaves of *Tectona grandis*, usually in lots of 400–500 forming a flat yellowish patch. The 1st stage caterpillars (which are greyish-yellow with dorsal and subdorsal lines of black velvety spots bearing dark bristles) feed gregariously and finely skeletonise the surface of the leaf in a manner similar to that of *Diacrisia obliqua confusa*. After feeding for about a week the caterpillars abandon teak as a food and the 2nd to 7th instars feed on other verbenaceous plants (e.g., *Clerodendron*, *Vitex*), the leaves of which are entirely eaten. The mature larvae are very hairy and black with lateral tufts of reddish-brown hairs; length $1\frac{1}{2}$ inches.

The life cycle in the monsoon season lasts about 8 weeks from egg to moth with a pupal period of 20 days. Pupation occurs deep in the soil in a cocoon of cast-off larval hairs, the moth crawls out by means of spurs on the fore tibiae.

Rao Y R, 1928 *Agr. Journ Ind*, XXIII, pp 39-41, figs 1-3, The function of the anterior tibial spurs in Amsacta albistriga.

Argina argus, A. cribraria and **A syringa** feed on *Crotolaria sericea* boring into the seed pods, the pupal period is about 4 weeks in September and is passed in a thin cocoon in the soil. There are 5 or more generations in the year.

Hutson J C, 1932, *Trop. Agr*, LXXVIII, pp 136, 137, Insect pests and green manuring

Creatonotus transiens feeds on *Cedrela toona*, *Ehretia laevis*, *Ficus religiosa*, and *Lantana aculeata*. It is often found in association with *Diacrisia obliqua* and is very similar in appearance and habits. The life-cycle between May and September takes about 45-50 days (egg 4 or 5, larva 35-38, pupa 7-9 days), there are 6 or 7 moults. Larvae pupating in December hibernate for 1 or 2 months

Beeson and Chatterjee N C., 1940, *Ind For Rec*, Ent, VI, No 3, pp 53, 54

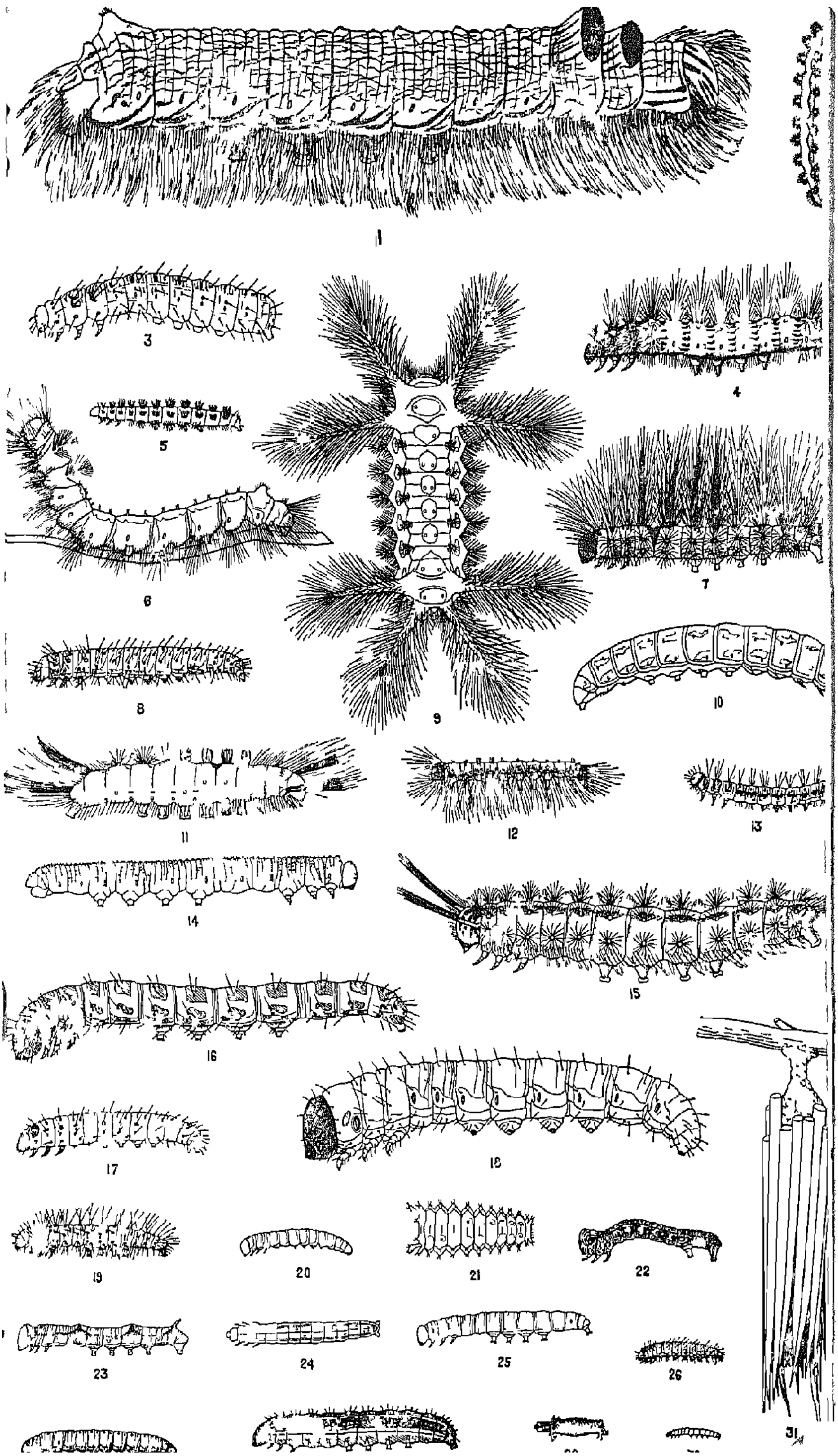
Diacrisia eximia feeds on the foliage of *Randia uliginosa*. **D. melanosoma** on *Girardinia heterophylla*, pupal period 30 days

FIG. 156. LARVAE OF 31 SPECIES OF LEPIDOPTERA

All caterpillars are reproduced natural size, see inch scale

1 Suana concolor, Lasiocamp
2 Parasa lepida, Limacod
3 Aegocera venulia, Noctu
4 Diacrisia obliqua, Arcti
5 Syntomis cyssea, Syntom
6 Taragama siva, Lasiocamp
7 Dasychira grotei, Lymantri
8 Lamoria adaptella, Pyral
9 Natada velutina, Limacod
10 Agrotis ypsilon, Noctu
11 Dasychira mendosa, Lymantri
12 Caviria ochripes, Lymantri
13 Hypsa ficus, Hyps
14 Catopsilia crocale, Pier
15 Trabala vishnou, Lasiocamp
16 Indarbela tetraonis, Indarbel
17 Hypsipyla robusta, Pyral
18 Phassus malabaricus, Hepial
19 Margaronia laticostalis, Pyral
20 Cladobrostis melitricha, Blastobas
21 Trypanophora semihyalina, Zygaen
22 Ectropis deodarae, Geometr
23 Ocinara varians, Bombyc
24 Hapalia machaeralis, Pyral
25 Inguia subapicalis, Noctu
26 Dichocrocis leptalis, Pyral
27 Tonica niviferana, Oecophor
28 Hyblaea puera, Hyblae
29 Tinea pellionella, Tine
30 Pammene theristis, Eucosm
31 Clania crameri, Psych

(SEE OPPOSITE PAGE)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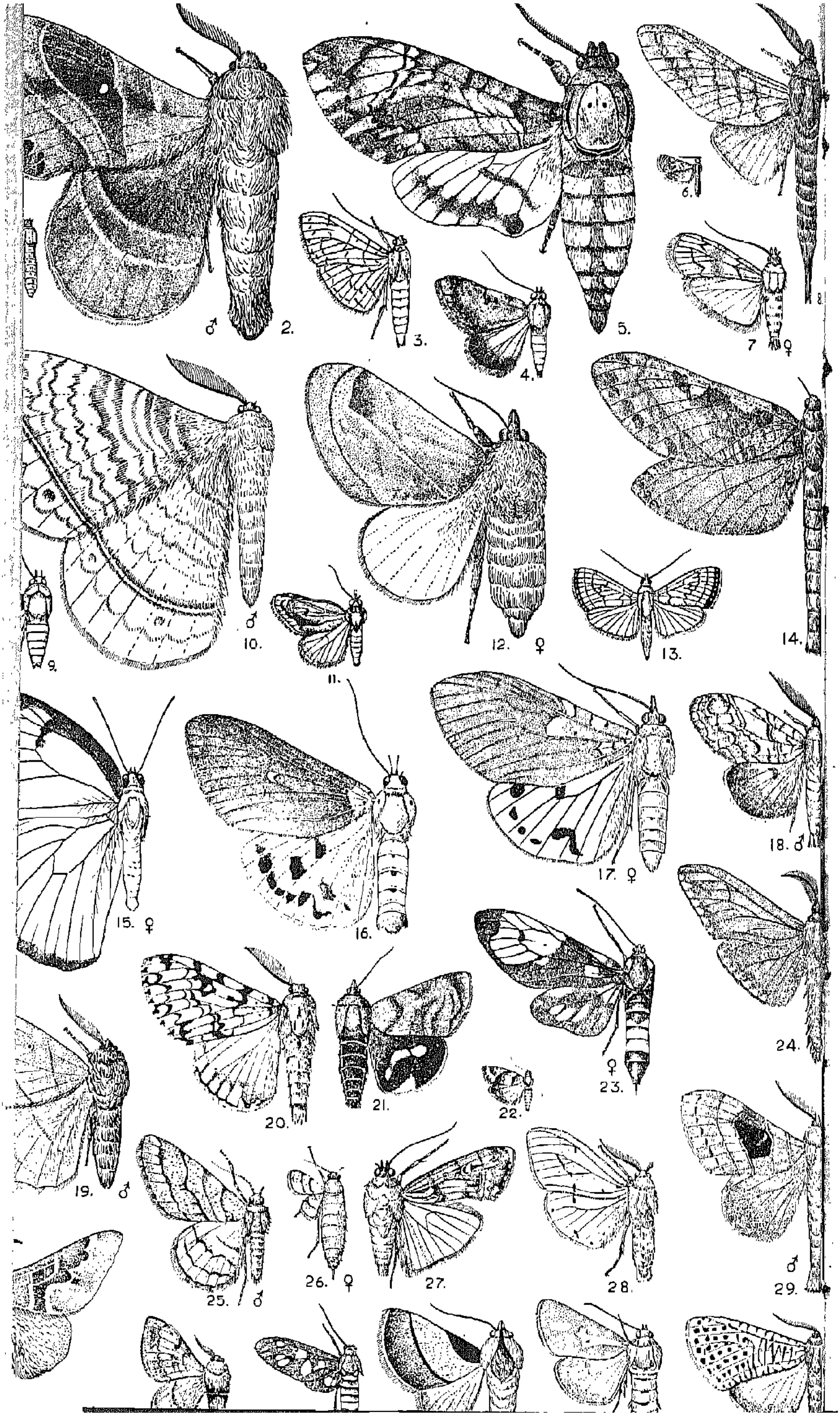

♂ 2.
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25. ♂
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♂ 29.

in October, November. **D. multiguttata** on *Gmelina arborea*; the pupal period in October is 6 days.

Diacrisia obliqua, in the colour form **confusa,** is a polyphagous oriental species. The moth is pinkish-buff coloured with a few black dots on the wings (span 1½–2 inches); the body is crimson with black dots. [fig. 157, No. 28 shows the male moth]. Several hundred eggs (1,600) are laid in a close layer without a protective covering on the leaf. The larvae hatch in 3 or 4 days and feed in colonies when young, skeletonising the surface of the leaf. Later they disperse and feed singly, eating the whole of the leaf-tissue. The hairy caterpillar [fig. 156, No. 4] is 1 to 1½ inches long when full grown, dark in colour at both ends, the abdomen with 7 broad, orange, transverse bands. The hairs occur in long brushes arising from tubercles on the segments and are dark at the thoracic and anal ends of the body and yellow over the greater

FIG. 157. MOTHS OF 34 SPECIES OF LEPIDOPTERA

All figures are natural size.

1 Cladobrostis melitricha, Blastobas
2 Lebeda nobilis, male, Lasiocamp
3 Dichocrocis evaxalis, Pyral
4 Plecoptera reflexa, Noctu
5 Acherontia styx, Sphing
6 Pammene theristis, Eucosm
7 Hypsipyla robusta, Pyral
8 Suana concolor, male, Lasiocamp
9 Ingura subapicalis, Noctu
10 Eupterote undata, male, Eupterot
11 Selepa celtis, Noctu
12 Natada velutina, Limacod
13 Hapalia machaeralis, Pyral
14 Phassus malabaricus, Hepial
15 Catopsilia crocale, fem., Pier
16 Hypsa alciphron, Hyps
17 Hypsa ficus, Hyps
18 Dasychira grotei, Lymantri
19 Trabala vishnou, Lasiocamp
20 Lymantria concolor, male, Lymantri
21 Hyblaea puera, Hyblae
22 Eucosma hypsidryas, Eucosm
23 Trypanophora semihyalina, fem., Zygaen
24 Clania cramerii, Psych
25 Ectropis deodarae, fem., Geometr
26 Ectropis deodarae, male, Geometr
27 Agrotis ypsilon, Noctu
28 Diacrisia obliqua confusa, male, Arcti
29 Metanastria hyrtaca, Lasiocamp
30 Taragama siva, male, Lasiocamp
31 Ocinara varians, Bombyc
32 Syntomis cyssea, male, Syntom
33 Parasa lepida, Limacod
34 Aegocera venulia, male, Noctu
35 Indarbela tetraonis, Indarbel

(SEE OPPOSITE PAGE)

part of the abdomen. Pupation takes place in the soil after 3 to 6 weeks in a reddish-brown cocoon covered with hairs. The moth emerges after 10–15 days. In south India the life-cycle varies from 5 to 8 weeks according to the temperature. From November to February in south India and to June in north India the insect hibernates and aestivates as a pupa. There may be 7 generations in the year in a tropical climate but only 3 in the neighbourhood of Dehra Dun where there are 2 generations during the monsoon season and a third beginning in September, October, which passes the spring and hot weather as a pupa.

This species is a pest of many agricultural crops and garden plants in India and feeds on numerous species of forest shrubs and trees including *Butea frondosa*, *Cedrela toona*, *Colebrookia oppositifolia*, *Lantana*, *Morus alba*, *M. indica*, *Tectona grandis*, *Vitex negundo*. Where lantana has been clean stripped by *D. obliqua* in the Central Provinces, teak advance growth suppressed by the lantana has been able to respond to the overhead light. Because of its occasional outbreaks in epidemic form on lantana, it has been considered a possible species to use for the artificial defoliation of lantana jungle as a preliminary to regeneration. It has a high reproductive potential but is severely parasitised and diseased and in consequence is unmanageable.

Beeson and Chatterjee N. C., 1940, *Ind. For. Rec.*, Ent., VI, No. 3, pp. 47, 54–56 (Indigenous insects of lantana).
Rao Y. R., 1920, *Mem. Dept. Agr. Ind.*, V. p. 238, Lantana insects in India.

Pericallia ricini defoliates *Cassia tora*, *Lantana*, *Ricinus communis*, *Tecoma grandiflora* and *Zea mays*. A generation occurs in June–August and another in August–October. There are 3 generations a year in north India. Larvae pupating in November in north India give rise to moths in May and June after a pupal period of about 6 months.

Roeselia nitida feeds on *Pieris ovalifolia* and *Quercus incana*.

BLASTOBASIDAE

SEED-BORERS, wood-borers, and predators are represented among the few species of this gelechioid family.

Fletcher T. B., 1920, *Mem. Dept. Agr. Ind.*, Ent., VI, pp. 128-131, Life histories of Indian insects, Microlepidoptera, Blastobasidae.
— 1933, *Imp. Counc. Agr. Res.*, *Sci. Mon.* No. 4, pp. 31-33, pl. XXIX, Life-histories of Indian Microlepidoptera, (2nd ser.) Blastobasidae.

The genus **Blastobasis** comprises species that are borers of the seeds of trees. Larvae of this group usually feed on seeds and dry refuse indiscriminately without being confined to particular species of plants.

Blastobasis crassifica, B. molinda, and **B. ochromorpha** bore in the seeds of *Shorea robusta*. **B. spermologa** is a widespread species attacking the seeds of *Dipterocarpus turbinatus*, *Shorea robusta;* also *Ficus glomerata*, *Polyalthia longifolia* and tea.

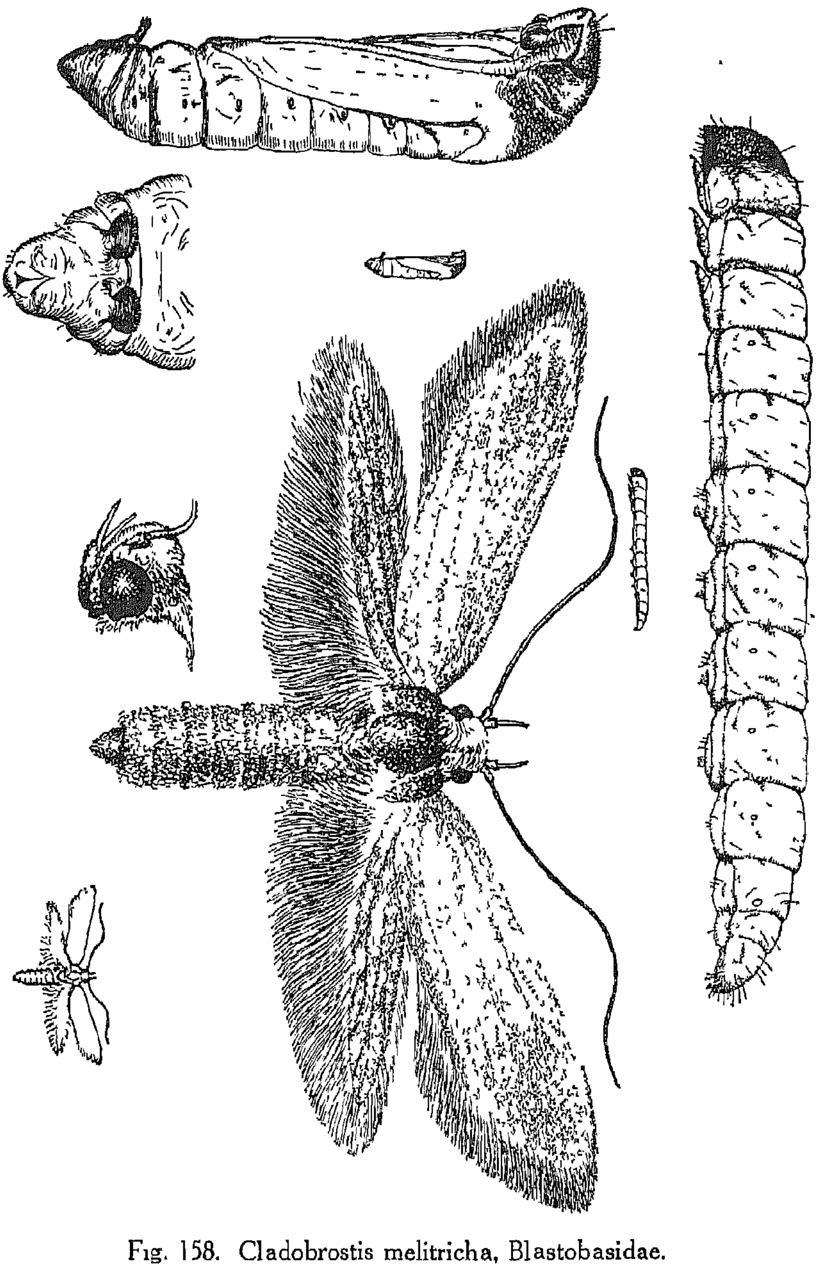


Fig. 158. Cladobrostis melitricha, Blastobasidae.
Small figures show natural size of moth, pupa and larva, head of moth and anal extremity of pupa most enlarged.

Larva 8 mm. long.

Cladobrostis melitricha is a borer of the living twigs of shisham trees. [figs. 158, 156, No. 20, 157, No. 1].

Life-history: Eggs are laid on the young shoots, usually leaders, and branches of pencil thickness of *Dalbergia sissoo.* The whitish larva [fig. 158] bores through the epidermis into the pith and excavates a tunnel several inches long, removing all the tissues except a thin outer layer and the walls of tunnels are stained black. Just before pupation the larva, 18 mm. long, cuts a biconical cavity which completely severs the shoot except for the epidermis. Pupation takes place without the formation of a cocoon below the girdled portion opposite a previously bored exit-hole. The moths emerge in June, July, after a pupal period of about three weeks. The moth [fig. 158] has elongated, narrow wings, pale fuscous in colour without markings and fringed with hairs; expanse 3/4 to 1 inch. Egg subcylindrical, brownish. Larva with 5 pairs of prolegs, cylindrical, whitish, 18 mm. long when full grown. Pupa [fig. 158] yellowish-brown, 11 mm. long. The stages are described and figured by Fletcher, 1933.

Economic importance: The attack of this species amounts to a heavy pruning of the crowns of shisham trees. The branches break off at the point of girdling, leaving a clean-cut conical depression at the end which resembles the work of *Sinoxylon* (Bostrychidae). Two or more larvae may work in one shoot with the result that several feet of growth may be destroyed. It is only abundant where young shisham trees are growing in open stands and are producing many weak branches from the lower bole.

Beeson, 1938, *Ind. For. Rec., Ent.*, IV, No. 1, pp. 18, 19, Guide to the insects of Dalbergia sissoo.

Fletcher, T. B., 1933, *Imp. Counc. Agr. Res., Sci. Mon.*, No. 4, pp. 32-33, pl. XXIX, figs. 1-5, (descriptions of stages).

Holcocera pulverea

This species occurs throughout the lac-growing districts of India and Burma. Its larva is a serious enemy of the lac insect but in most localities it is not so important as the other moth-predator of lac, *Eublemma amabilis* (Noctuidae).

Life-history: Eggs are laid on the cells of a living lac encrustation and the caterpillar on hatching out tunnels its way through the lac from cell to cell feeding on lac insects; it also eats dead lac insects and to some extent the lac itself. The excrement of young larvae is white and granular and that of older larvae takes the form of irregular crimson pellets strung together with a loose but tough web of silk. The number of lac cells that one caterpillar may destroy during its life varies with the length of the larval stage from about 10 to 40 mature lac females, or about 60 to 450 larval cells. Pupation occurs in a cocoon of

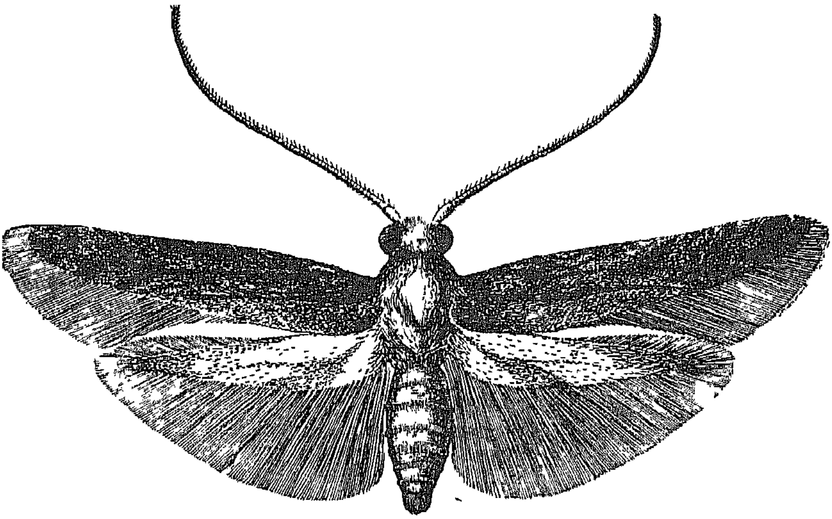


Fig. 159. Male moth of Holcocera pulverea, Blastobasidae.

tough white silk among the lac debris. The mature larva is about 10×2 mm., and the pupa about 5×2 mm.

The length of the life-cycle varies from 214 to 30 days. Eggs laid in February produce moths emerging in April–May (egg 10, larva 48, pupa 8, complete cycle 66 days). Eggs laid in March produce moths in April-June (55 to 80 days, average 67 days). Eggs laid in April give rise to moths in May, June (average 56 days). The moths of May and June complete a generation in July, August (average life-cycle 41 days) but may develop in as little as 32 days. Eggs laid in July produce moths in August, September in 34 to 60 days (egg 4, larva 34, pupa 9, complete cycle 47 days). Eggs laid in August give moths in late September-early October (30–49, average 38 days). Eggs laid from September onwards may give rise to a short generation completed in mid-October (40 days); or to larvae that hibernate wholly or partially and produce moths at any time from October to February with a maximum life-cycle of 214 days. These individuals emerging in the cold weather may live several weeks and give rise to intermediate broods tending to mature in March–April with life-cycles of 175 to 95 days (e.g., egg 5, larva 160, pupa 10 days).

There are thus 6 generations per annum possible at the most rapid rate of development, while the average rate allows 5 full generations and a partial sixth. The larva, pupa and moth are described and figured by Misra and Gupta in the reference given below. [fig.159 shows the male moth].

Economic importance: The lac crop during the period July to February (Aghani and Katki) is liable to greater damage

than is the crop of November to July (Jethwi and Baisakhi). *H. pulverea* is not so injurious to lac growing on the tree as is *Eublemma amabilis*, owing to its lesser abundance. Damage continues in the stick-lac stored in godowns where it is as abundant as *E. amabilis*, and is a pest of equal importance.

LITERATURE:

Fletcher T. B., 1920, *Mem. Dept. Agr. Ind.*, Ent., VI, pp. 130-131, Life histories of Indian Microlepidoptera.

Glover P. M., 1931, *A practical manual of lac cultivation*, pp. 57, 58.

Imms A. D. and Chatterjee N. C., 1915, *Ind. For. Mem., Zool.*, III, p. 31, 32, pl. 7, fig. 24.

Misra C. S., 1929, *Agr. Res. Inst.*, Bull. 185, pp. 93-94.

Misra M. B. and Gupta S. N., 1934, *Ind. Journ. Agr. Sci.*, IV, V, pp. 832-864, pl. LV, figs. 1-5, The biology of Holcocera pulverea Meyr., its predators, parasites and control.

BOMBYCIDAE

A SMALL family but of great economic importance because of one of its species, *Bombyx mori*, the Mulberry Silkworm, from which the bulk of the world's real silk is obtained.

Silk: Silk is a secretion produced by most caterpillars and many other insects and spiders. It is formed as a thick gummy fluid in the silk-glands (salivary) which are long sack-like structures within the body of the insect, ending in two fine ducts that open on to the lower lip; when exposed to the air this viscous fluid dries rapidly and hardens to a strong filament. Silk is used by insects for a variety of purposes but in the Lepidoptera the chief purpose is the formation of a cocoon for the protection of the pupa. The outer layer of the cocoon, which, of course, is the first part to be produced, is formed of irregular threads that fix it in position, but the inner layers are usually formed by the secretion of a continuous thread over 1,000 feet long which is regularly disposed in concentric unbroken strata. Some caterpillars apparently rest at intervals during the spinning of the cocoon and in such cases distinct discontinuous layers are the result. It is only in two families and in a few species of these families (Bombycidae and Saturniidae) that the strength, quality and quantity of the silk is of commercial value and can be used for the manufacture of silk thread and cloth.

A gut used for surgical and fishing purposes is made from the intestines of silkworms which would otherwise form the silk-secreting organs. These are extracted dried and packed in bundles. Millions of worms are killed at a time for this purpose in Italy, Spain, Formosa and Japan and the industry is growing in importance in India.

The silkworms reared commercially in India are The Mulberry Silkworm, *Bombyx mori*, the Eri Silkworm, *Philosamia ricini*, the Tussar Silkworm, *Antheraea paphia*, and the Muga Silkworm, *Antheraea assamensis*. Only the first species belongs to the family Bombycidae: the other three are of the family Saturniidae

or Wild Silk Moths (see Saturniidae).

LITERATURE ON BOMBYCIDAE:
Hampson G. F., 1892, *Fauna Brit. Ind.*, Moths, I, pp. 31-40, figs. 16-23, Bombycidae.

Bombyx mori, the Mulberry Silkworm.

History: This species was probably indigenous either in India or in China, where it had been domesticated for centuries but it no longer occurs wild anywhere. The Chinese cultivated it for more than 3,000 years (from before 2,255 B. C.) and kept the art of sericulture a secret from the rest of the world, prohibiting the disclosure of information and punishing with death any attempts to export eggs or live cocoons. About 555 A. D. it was at last introduced to Europe—by two monks sent as spies to China who brought back to Constantinople eggs concealed in a pilgrims' staff. Thereafter the cultivation spread and flourished in Mediterranean and Asiatic countries, including India, Burma and Thailand Under domestication *B. mori* has evolved into numerous races producing cocoons that vary in size, shape and weight and in colour from yellow to white; some races have an annual generation (univoltine) and are characteristic of regions with a long winter and a short hot summer, others have 2-7 races a year (multivoltine) especially in hot, humid climates. The moths have degenerated; the female is heavy-bodied and feeble-winged and is disinclined to fly. The larva is strongly gregarious, rarely attempting to wander, and readily feeding on finely chopped leaves in open baskets. "For more than 35 centuries it has toiled ceaselessly for man; countless generations laying their eggs, eating the mulberry leaves provided for them in the larval stage, spinning their cocoons, and then dying—a perpetual sacrifice to man's and woman's demand for adornment" (Metcalf and Flint).

Mulberry, *Morus alba*, is the sole food-plant but this tree itself is propagated in numerous varieties (800 are known in Japan), is grown in different forms such as coppice, bush and tree, and under different treatments and in different climates, so that the foliage produced varies very considerably in its quality, nutritive value and effect on the health and productive capacity of the silkworm.

Sericulture: In recent years much has been done by cooperative action to improve the sericultural industry in India and Burma. An Imperial Sericultural Committee was formed in 1934 and an All-India Sericultural Conference meets annually since 1939. Research is in progress on all aspects of the production of reeled and spun silk and the manufacture of silk yarn and fabrics, particularly in the Provinces of Assam, Bengal, Madras and the Punjab with the assistance of annual subsidies from the Government of India, and in the States of Kashmir and Mysore. On the biological side these activities cover the production and supply of disease-free eggs or 'seed', refrigeration, etiology of

silkworm diseases, hybridisation and genetical studies, as well as the propagation-cultivation, and cropping of mulberry varieties.

R e a r i n g: As a cottage industry the rearing of silkworms is conducted on the following system. Eggs are obtained by confining the mated female moth under a metal cone or ring on a sheet of paper; she will lay about 300–400 eggs in 2 or 3 days. After death the body of the moth is pounded up with water and examined microscopically for the presence of pebrine and other diseases; if infected her layings are rejected. Examination of moths and certification of eggs is done at a centre, usually state aided or controlled and termed a grainage: (much of the terminology of sericulture is derived from French or Italian words). The eggs of univoltine races take several months to hatch. Refrigeration is used to control hatching (accelerate and also postpone). The worms are fed with finely chopped leaves of mulberry in flat open baskets kept in racks inside the rearer's house. Simple but ingenious methods are used to clean the trays and renew the food-supply frequently (5–9 times a day) during the larval period which lasts 3–5 weeks. The full-fed worms, 3 inches long, are supplied with a special tray having a spiral partition (chandrika) and left to spin their cocoons, a process which takes about 3 days. Cocoons are removed and the pupae inside are killed by baking or exposing them to the heat of the sun; the cocoons can then be stored until required for reeling.

R e e l i n g: Whether done on a primitive reeling appliance (charkha) in a village hut or in a filature with its batteries of power-driven reels, the process of reeling is fundamentally the same: the cocoon is soaked in a basin of hot water which softens the adhesion of the silk filament and allows it to separate freely; several free ends are picked up from several cocoons floating in the basin and the filaments are led through a small eyelet and over guides (croissure) which twist the separate filaments into one thread that is passed by a distributor on to a large reel or frame; from the frame it is later rewound on a spool or in a hank. This product is raw silk or 'reeled silk'. The waste from the outer layers, floss, pierced and damaged cocoons, charkha waste, etc. can be combed and teased by machines into short straight parallel lengths which are spun into a continuous thread of 'spun silk'. It requires more than 25,000 cocoons to make a pound of silk and it is estimated that 80 to 100 million pounds of raw silk are sent to the world's markets every year, of which India consumes about 4 million pounds, and produces only 1½ million pounds, half of which comes from Mysore.

LITERATURE:

De M. N., 1915, *Agr. Res. Inst. Pusa*, Bull. 48, First report on the experiments carried out at Pusa to improve the mulberry silk industry.

— 1917, *tit. cit.*, Bull. 74, Second report.

Hutchinson C. M., 1917, *Agr. Res. Inst. Pusa.*, Bull. 75, The pebrine disease of silkworms in India.

Jameson A. P., 1922, *Report on the diseases of silkworms in India.*
Lefroy H. M. and Ansorge E. C., 1916, *Report on an inquiry into the silk industry in India*, I, The silk industry.
Mysore Agricultural Calendar from 1934.
Proceedings of the Imperial Sericultural Committee from 1934.
Papers presented at the First All India Sericultural Conference, 1939.

Gunda javanica is a defoliator of *Ficus elastica* plantations. In India the caterpillars appear in August and pupate in October, November with moths in December. Moth greyish-brown, expanse 2½ inches.

Ocinara signifera defoliates *Ficus cunia* and *F. glomerata*. Eggs are oval flat-topped shapes laid in rows; one female may lay about 40 lots of eggs totalling 250. Hatching takes place in 4–7 days in April. The larval period is 9–18 days in April. Pupation occurs in a yellow cocoon about 18×10 mm. The pupal period is 6–7 days at the end of April. Eggs of the next generation take 5–7 days to hatch in May and the caterpillars feed for 9 to 11 days. The pupal period in May, June is 6 or 7 days.

Ocinara varians feeds on various species of *Ficus* throughout India and Burma and is sometimes a pest of rubber plantations and cultivated fig trees and plantations of *Artocarpus integrifolia* in Ceylon. The larva [fig. 156, No. 23] about 3/4 of an inch long, is speckled with pink and brown, without tufts of hairs but with a horn or tail-like projection on the last abdominal segment but one. The surface-layers of the leaf are eaten away in patches and later irregular holes are cut out. Pupation occurs in a compact oval white cocoon. The moth [fig. 157, No. 31] is pale brownish-grey with an expanse of about an inch. The life-cycle occupies from 4 to 8 weeks with a pupal period of about 12–17 days.

1936, *Trop. Agric.*, LXXXVI, p. 263, Some common insect pests of fruit trees.

CARPOSINIDAE

Meridarchis reprobata feeds in the fruits of *Eugenia jambolana* and olive, and **M. scyrodes** in the fruits of *Zizyphus jujuba*.

Fletcher T. B., 1920, *Mem. Dept. Agr., Ind.*, Ent., VI, p. 33, Life-histories of Indian insects, Microlepidoptera, Carposinidae.

COSMOPTERYGIDAE

MANY species of this gelechioid family mine blotches in the living leaves of trees and especially of Gramineae; others feed on dead plant-refuse.

LITERATURE:

Fletcher T. B., 1920, *Mem. Dept. Agr. Ind.*, Ent., VI, pp. 97-105, pls. xxii-xxiii, Life-histories of Indian insects, Microlepidoptera.
— 1928, *Catalogue Ind. Ins.*, Part 16, Cosmopterygidae.
— 1933, *Imp. Counc. Agr. Res., Sci. Mon.*, No. 4, pp. 1-8, pls. i-vi, Life-histories of Indian Microlepidoptera.

Ascalenia antidesma binds together and feeds on the leaflets of *Acacia catechu*; when full fed the larva, 4 mm., drops by a

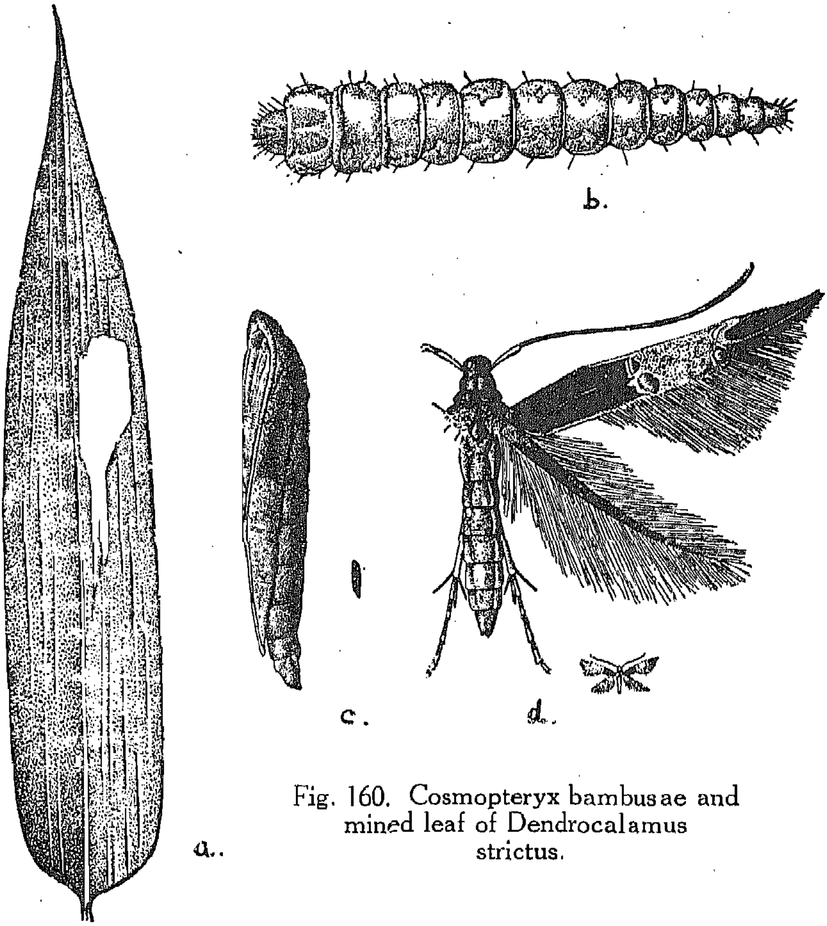


Fig. 160. Cosmopteryx bambusae and mined leaf of Dendrocalamus strictus.

thread and pupates in a cocoon among leaves or in the soil; the pupal period lasts 6 days in July. Fletcher, 1933, *tit. cit.*, pp, 6, 7, pl. V. **A. gastrocosma** also feeds on the leaflets of *Acacia catechu*, folding or binding them together; the pupal period lasts 5 days in May, June. Fletcher, 1933, *tit. cit.*, p. 7, pl. VI. **A. pachnodes** bores the green stems of *Tamarix gallica.*

Batrachedra silvatica breeds in twigs of *Pinus longifolia* attacked by *Ripersia resinophila* (Coccidae), presumably feeding on the dead bark and bracts.

Cosmopteryx bambusae [fig 160] forms mines in the leaves of bamboos. The larva eats away a patch of internal tissue, leaving intact the outer layer of cells, which turn yellowish-white on dying. When fullgrown (about 7 × 1 mm. long) it cuts the edge of the mine and rolls the layer inwards pupating inside the rolled tissue.

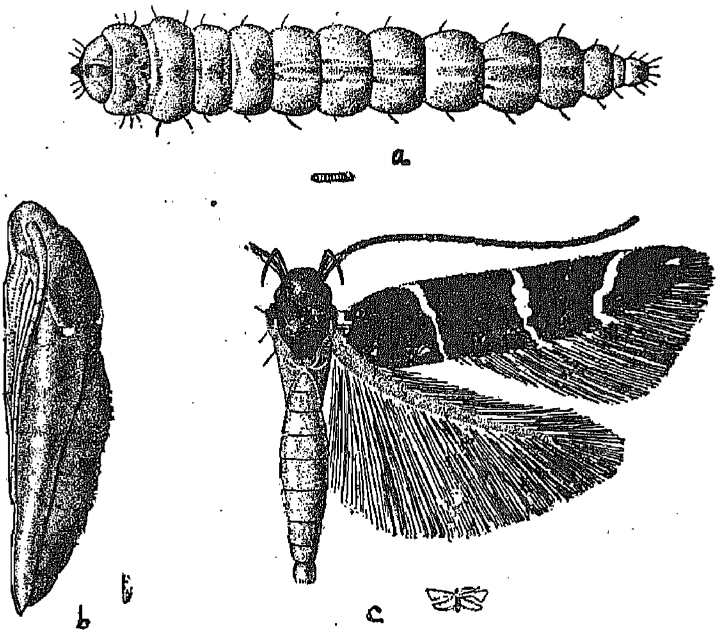


Fig. 161. Labdia callistrepta, Cosmopterygidae.

Fletcher, 1920, *tit. cit.*, pp. 102, 103, pl. xxiii, fig. 1 *a-d*.

Eumenodera tetrachorda. The larva bores into the needle of *Casuarina equisetifolia*, hollowing it out up to the apex but leaving the epidermis intact. Pupation occurs in the hollow. The attacked needles dry and fall; young plants may be rendered leafless. It is most injurious in new plantings during the rains in July, August.

Heterotactis quincuncialis binds together and feeds on the leaves of *Acacia catechu*.

Labdia callistrepta is a leaf-miner of *Vitex negundo* and *Tectona grandis*. The larva tunnels under the epidermis on the upper surface of the leaf, producing prominent blisters which are brownish on teak and whitish on *Vitex negundo*. Several blisters may be made on one teak leaf and in bad attacks the whole leaf-surface of the greater part of the foliage of a tree may be affected. The larva [fig. 161] when full grown is about 5 mm. long and is capable of leaving its tunnel in a drying leaf and making a new mine in another leaf. Pupation occurs in the larval tunnel in a white cocoon covered with particles of frass. There are several generations throughout the year with a pupal period of 4 to 7 days. The moth [fig. 161] is black with 3 white transverse lines on the forewing which is fringed below as is also the hindwing. It shelters beneath fallen leaves on the ground during daytime.

Fletcher T. B., 1920, *Mem. Dept. Agr., Ind.*, Ent. vi, p. 101, pl. xxii, (Pyroderces callistrepta).

L. xylinaula mines the needles and shoots of *Casuarina equisetifolia*.

Pyroderces falcatella occasionally infests stored stick lac, mainly as a scavenger feeding on dead lac insects but damaging the lac in the process. It also occurs with *Tachardia albizziae* and with *Dactylopius* sp. (Coccidae).

Fletcher T. B., 1920, *tit. cit.*, p. 99 (Anatrachyntis).
— 1933, *tit. cit.*, p. 3, pl. ii (Pyroderces).

P. diplecta defoliates and feeds on the flowers of *Borassus flabellifer*. **P. simplex,** a widespread species, feeds in vegetable debris such as dry or rotten seeds and fruits of trees, Fletcher *tit. cit.*, 1920, pp. 97–99.

Stagmatophora acanthoda mines the leaves of *Vitex negundo*, making zigzag tunnels 1/2—1 inch long below the upper epidermis. A pupal stage of about a week (in June, July) is passed in the larval mine.

COSSIDAE

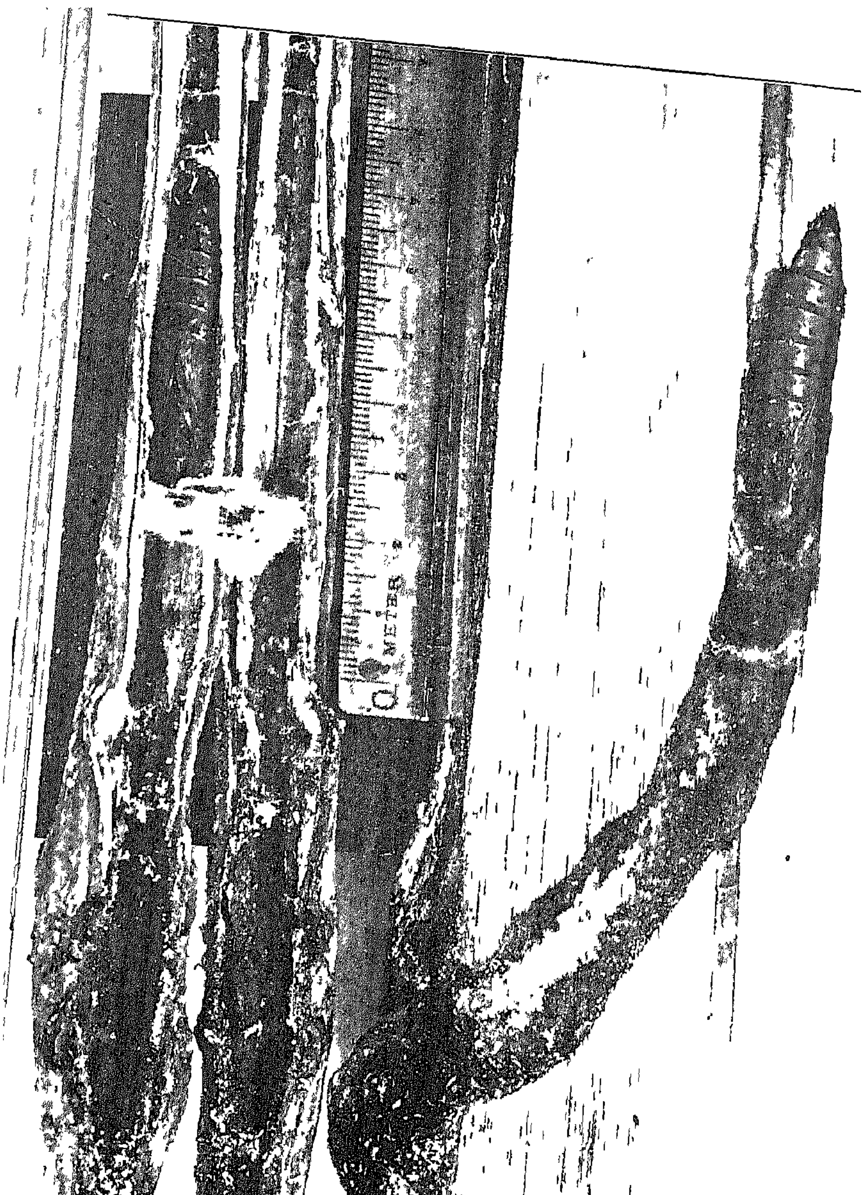
NEARLY all larvae of the COSSIDAE are borers of the wood of living trees; other species bore in herbaceous non-lignified stems; about 25 species are recorded from India. The moths are known as Leopard Moths, Goat Moths, Carpenter Moths or Bee-hole Borers and in several species have a wing-span of 4–6 inches. An Australian species of *Xyleutes* has a wing-span of 10 inches with a larva 7 inches long. The attack of the tree-borers does not appreciably affect the health of large trees but it spoils the timber and the damage is not revealed until the log is sawn up. Several species of Indian trees are attacked by unidentified Cossidae, e.g. *Acer campbelli, Alseodaphne semecarpifolia, Juglans regia.*

Hampson G. F., 1892, *Fauna Brit. Ind.*, Moths, I, pp. 304-314, figs. 209-214, Cossidae.

Cossus acronyctoides is a borer of the stems of living *Tamarix articulata* in the Punjab. The moths emerge in May.

Cossus cadambae is a borer of living *Tectona grandis* in south India, producing small tunnels in the wood similar to the beeholes of the Burmese *Xyleutes ceramica*. Eggs are laid at snags or wounds caused by the dying back of branches, or fires, etc. The larva is bright red in colour and reaches a length of about 1½ inches. It bores into the sound wood a tunnel of irregular shape usually wider than the diameter of its body and a few inches long. From the shelter of this tunnel it feeds on living bark in

Fig. 162. Teak plantation made in Nilambur, Madras, in 1846; note man standing at the base of the tree in middle foreground; photographed in 1934. Xyleutes ceramica does not occur in Indian teak forests.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the vicinity probably taking ten or eleven months in the larval stage. Pupation occurs in the tunnel and the pupa wriggles towards the mouth in order to release the moth. Emergence takes place in the spring.

The attack of this borer is limited to trees of poor quality that are unhealthy or badly treated by lopping, coppicing or burning. Dead wood in the form of scars or snags appears to be an essential predisposing factor as healthy trees in the vicinity of seriously infested individuals remain immune.

Xyleutes ceramica. The Beehole Borer.

The Beehole Borer is the most important pest of *Tectona grandis* in Burma. It ranges from New Guinea to Java and the north of Burma but does not occur in India and Ceylon; a map showing its distribution in Burma with reference to teak forests and isohyets is given by Atkinson, 1936. *Callicarpa arborea, Clerodendron infortunatum* and *Gmelina arborea* are occasional alternative food-plants. *Vitex parviflora* is a food-plant in the Philippines. It is an interesting and unsolved problem whether its ancestral food-plant is teak or another species of Verbenaceae.

Life-history

Short accounts of the life-history suitable for translation into local languages are given by Atkinson, 1936 and Garthwaite, 1940.

M o t h : The moth has narrow forewings pale brown with white scaling and variable patterns in black which give a cryptic resemblance to the bark of a tree; the black scales are mainly in the form of spots along the outside edge of the wing, with longitudinal lines or streaks near the centre and irregularly marbled patches between the veins on the outer and lower borders; near the outer angle is a fairly conspicuous white patch with dark markings and margined with black; the thorax is greyish-white. Length 40–80 mm., wing-span 80–160 mm., the average size is about 100 mm. = 4 inches; the female is on the average larger than the male. All stages are illustrated by Beeson, 1921.

The female moth lives for a few days, not more than 5, and is discovered soon after emergence by males which fly from considerable distances away. Both sexes are strong fliers.

O v i p o s i t i o n : She lays thousands of eggs (up to 50,000), attached in strings in the crevices of bark. The incubation-period is obout 10 days at 96°, 97° F. to 20 days at 82° F. Temperature affects the viability of the egg more than humidity does.

Fig. 163. Xyleutes ceramica, the beehole borer. Beeholes in a young teak sapling (left) and a much older pole (right), showing pupa in pupal chamber with silk wad unbroken; nearly full size, see centimeter scale,

Young larva: After the larva has hatched it spins a long filament of silk which acts as gossamer and carries it away on a moderate breeze; by this mode of transport larvae hatching gregariously are dispersed widely; a larva can survive without food for 6 days after hatching provided the temperature and the humidity are not high. At a suitable crevice in the bark of a living teak tree the larva enters, protecting itself with a silk web until it has bored in completely. There is a very high mortality of larvae in this instar. Eventually a survivor reaches the surface of the sapwood and excavates a shallow patch which is the beginning of the actual beehole; this is deepened gradually into a tunnel which, in the course of 4 months by July or August, reaches a length of 1–2 inches in the sapwood and is scarcely the diameter of a pencil. In the following months the beehole is carried into the heartwood at an upward angle of about 45° for 2 or 3 inches or so and then vertically upwards for another 6 8 inches. A fully developed larva makes a beehole about 10 inches long overall and 1 inch in diameter; less robust larvae may cease work when they have tunnelled 6 inches. Fig. 163 shows, right, a beehole in longitudinal section in a teak pole, and, left, a beehole in a slender sapling. Some larvae, finding their original location unsuitable because of insufficiency of food (callus and sap) or because of disturbance by woodpeckers or other enemies, leave the small beehole and wander elsewhere and bore in at a new site on the same tree or on another one. Small beeholes also result from larvae that are killed by parasites.

The mature larva, about $2\frac{1}{2}$ inches long, is cylindrical tapering at both ends, smooth, hairs inconspicuous, banded transversely with pink and white on each segment, the pronotum with a rough surface formed by numerous backwardly directed teeth; it is the only pink and white banded caterpillar with a rough shield on the thorax that is known to bore into teak.

Food: The food of the larva is not the wood excavated from the beehole but the bast and callus of new bark formed in the wound around the mouth of the beehole. This feeding-chamber is a stellate or lobed excavation the arms of which extend into the living bark and outermost layers of the sapwood and it covers an area of 3 inches square; over one or more of the arms circular ejection-holes are drilled through which excrement and frass is pushed out and which are closed with a papery operculum when not in use. A few lumps of moist detritus and a slight bulge in the bark are all that can be discerned on the outside as evidence of a live borer within. As fast as the nutritious callus-tissue is formed by the tree it is browsed down by the larva, but when the larva retires for pupation the overgrowth is laid on unimpeded and in vigorous trees so rapidly that it may block the mouth of the tunnel and trap the pupa alive when it descends.

After a larval life of nearly one year, or abnormally of two seasons or two years, the larva clears a free passage in its beehole, closes the exit-hole with a circular disc of silk and debris, retires to the upper end of the beehole and shuts itself off with a loose wad of pale or reddish-brown strands of silk.

Pupation and emergence: The pupa lies in the chamber so formed with its head directed downwards and the cast larval skin behind. Fig. 163 shows a pupa in each of the 2 beeholes with the silk wads unbroken. After 2 or 3 weeks the mature pupa pushes through the silk wad which is penetrated by the frontal spine and flattened by the thorax against the walls of the beehole. The rows of backwardly directed teeth on the abdominal segments give the pupa leverage in its progress ; as the abdomen bends to and fro the teeth on opposite sides of the segments alternately slip and grip and thrust the pupa foward. On reaching the mouth of the beehole the frontal spine ruptures the operculum closing it and the pupa passes along a groove in the sapwood chamber and on through the thin disc covering the exit-hole. Here it projects the anterior half of its body into the free air and after spiral contortions and internal pressure it ruptures the various sutures of the pupal skin so that the moth can crawl out on to the bark. The moth takes about 10 minutes to expand its wings after which they are upheld in contact for 20–30 minutes to dry off and stiffen. The empty pupal skin remains protruding from the bark for many days after emergence. The emergence-period begins in late February in the south and progressively later to May in the north of Burma and may be confined to 3 or 4 weeks in any one locality.

Occlusion of beehole: By the end of the rains following emergence, except in very suppressed trees, the mouth of the beehole is completely occluded by two lobes of callus which extend into the cavity for a short distance; on the bark-surface outside a scar is still visible. Then the wood of the annual rings of subsequent years is laid on, the sapwood dies and becomes heartwood and any outward sign of the buried beehole disappears. Since a teak tree may be attacked throughout its life, the earliest beeholes lie in the heart of the log and the younger ones lie towards the outside.

It is possible to determine the exact age of a beehole and the year of its formation from a cross-section of the log by counting and dating the annual rings that overlie the pore-ring affected in the year of attack. By cutting up sample trees in sections and analysing the material it is possible to recapitulate the history of beehole-incidence in an area.

Accumulated damage: When a teak tree is felled in a thinning or at the end of the rotation it contains the accumulated effects of attack by *X. ceramica* throughout its life, viz., full-sized beeholes, abandoned beeholes, parasitised beeholes,

young larval feeding-scars and woodpecker-holes.

The ecology and economy of this pest offer several unique problems: (a) it does not appreciably retard growth or increase mortality, (b) the damage accumulates annually throughout the life of the tree but is not discovered till the timber is sawn, (c) the attack is heavier on vigorous trees than on unhealthy or suppressed trees, (d) the population of the pest is very small and remains fairly constant for long periods and there are no epidemics.

Incidence of beehole in Burma

Rainfall: There is very considerable variation in the abundance of *X. ceramica* as expressed by the beehole-incidence obtaining in teak forests and plantations in Burma; it varies from practically complete absence in Allanmyo and Ataran to an extremely high incidence in Thaungyin. The average annual rainfall of a locality is a sound index of the severity of its beehole-damage which increases with increasing rainfall; optimum conditions exist between the isohyets of 70″ and 110″, but above 150″ and below 55″ conditions become less favourable. It is improbable that rainfall has a direct effect on the abundance of the insect; it is more likely that it serves as an index of a meteorological complex in which the atmospheric temperature and humidity of the hot weather are important.

Vertical distribution: The vertical distribution of beeholes in the trunk of an average tree varies progressively through its life. In young trees up to an age of 25 there is a definite preponderance of beeholes in the lower portion of the bole, the total number of beeholes in the whole tree appearing in a series steadily diminishing from the base to a point above which the timber is not yet big enough for the formation of a normal beehole; at about 25 to 30 years old the curve for beeholes plotted against height tends to straighten in its lower half, i.e., the incidence of beeholes becomes fairly uniform throughout the lower bole; from 30-35 up to the age of 60 the curve is parabolic and its peak, i.e., site of maximum beeholing, moves up the bole as the age of the tree increases; at 60–70 years old the peak approaches or reaches the top of the bole, i.e., junction with the crown. At the maturity of the tree the distribution of beeholes is in an ascending series throughout the length of the marketable bole.

The relative increase in the incidence of beeholes in the upper part of the bole after height-growth has ceased and the position of the crown branches is fixed, is believed to be due to (a) increased concentration of larval attacks in the upper bole due to negative geotropism, and (b) relatively greater survival of bored-in larvae due to superior nutritive value of bark in the upper bole.

Horizontal distribution: It is the normal experience

in milling teak that the degree of beeholing increases towards the centre of the log. The volume of a tree increases at a faster rate than the population of the borer, which results in the outer zones of the log showing a lesser degree of beeholing, per unit of volume, than the inner. The fact that the normal course of a beehole is centripetal for a radial distance of about 3 inches, accentuates this internal concentration. Only when growth is very poor or stagnant does the borer-increment surpass the wood-increment and increase the beeholing towards the periphery.

Age-beehole and volume-beehole incidences

The incidence of beeholing of a single tree or of a crop in a locality is dependent on 3 variables—age, volume and rate of growth and can be expressed by numerical indexes based on several standards, viz., age-beehole, volume-beehole, girth-beehole.

Age-beehole incidence: The biological incidence—as contrasted with the economic incidence—is best shown by an age-beehole curve, i.e., the mean annual incidence in beeholes per tree. The age-beehole curve (a summation curve) progressively rises; the current annual incidence for the individual tree may fluctuate widely, nevertheless the mean annual incidence for the mean sample tree increases steadily though very slowly. The reason for this seems to be that in an ageing crop on a given area the number of trees gradually decreases, the surviving trees increase in size and the locally born borer-population, which started at zero, is tending to increase annually. Hence under the laws of probability the number of attacks per tree or per unit of tree-surface-area will increase. The trend of age-beehole curves is indicated by the following examples:—

Age	10	20	30	40	50	60	Years
a	0	0	1	2	7	15	Beeholes
b	0	3	10	25	44	65	per
c	3	14	25	47	87	111	tree
d	15	53	100	165	—	—	

These figures are for the number of beeholes in the bole of one tree at successive ages (and exclude the top and crown branches). *a* represents a light degree of beeholing, *b* is a moderate incidence, *c* is very severe and *d* is abnormally severe, the wood being "riddled with beeholes". An attack of 1 beehole per tree per year at any period is a very heavy incidence commercially. In a very old tree including the crown branches there may be hundreds of beeholes; the largest number determined by analysis and counting is 511 in one square.

Volume-beehole incidence: The mean annual incidence of beeholes rises steadily in relation to increasing age but it falls in relation to increasing volume; in other words the timber-increment outstrips the borer-increment (if the volume-increment is maintained normally). It follows that, whatever the local beehole-incidence may be, the faster the timber can be grown the greater will be the volume of comparatively beehole-free timber

that can be produced. The volume-beehole curve gives the best index of the economic incidence.

The girth-beehole curve is another similar but less accurate method of expressing the relationship between beeholes and volume and reveals the same conditions.

Even-aged incidence: The characteristics described in the foregoing sections apply to the mean sample tree of the stand at successive ages. Very similar characteristics are displayed in an even-aged stand by the mean trees of successive volume (or girth) classes; at any age in an even-aged crop the largest or dominant trees have more beeholes than the smaller or suppressed individuals. The increase in the number of beeholes is not directly proportional to the increase in volume or girth but follows it more or less parabolically. The following is an example of actual incidence in 5 girth-classes of an even-aged plantation:

Girth-class	1′ 1″–1′ 6″		1′ 7″–2′ 0″		2′ 1″–2′ 6″		2′ 7″–3′ 0″		3′ 1″–3′ 6″
Average beehole incidence	0·83	+0·43	1·26	+0·56	1·82	+0·36	2·18	+0·12	2·30

The relationship between volume and beehole in an even-aged stand is probably similar to that produced between these two factors as a result of age. It follows that whatever the local beehole-incidence may be, the greater the proportion of trees falling in the highest girth-classes of an even-aged stand, the greater will be the volume of comparatively beehole-free timber in the final crop.

Population-density: No epidemics of *X. ceramica* have ever been recorded. Fluctuations in the population produce beehole peak-years every 5–6 years in some localities and every 10–12 years in others. Considered in terms of the number of moths present on a given area on one day of the flight-season, that is, its population-density, the species is very uncommon; a population of 20 moths per acre may be rated as a high incidence. As soon as the eggs are laid the population may be multiplied by 20,000 but it lasts for only a short time as the mortality at this stage is very high.

Incidence in natural forest and plantation.

Opinions have varied widely as to the economic importance of *X. ceramica* in teak plantations and in natural forests. At one period it was accepted that plantation teak is much more heavily beeholed than natural forest teak in any given locality. Analyses of the frequency of beeholes on the faces of teak boards sawn in the Rangoon mills suggested that beeholing was 3 times as bad in plantation timber as in natural teak from neighbouring areas. Modern evidence shows that significant comparisons cannot be made without taking account of the age and rate of growth of the trees. The true or biological incidence of beehole is likely to be heavier in plantations than in natural forest, *other conditions being equal*, but it is considerably less than three fold, particularly

in areas of heavy incidence.

This difference in the biological incidence may be offset commercially by the more favourable volume-beehole ratio in the final yield of plantations. Much of the natural teak timber is and always will be more severely damaged by beehole borer than much of the existing plantation timber, and only the very worst of the latter will have difficulty in finding a market. The climatic factors are more important in determining the degree of beeholing that is normal for a locality, than is the silvicultural system.

The fast growth of plantation timber serves to accentuate the natural centripetal tendency for beehole-damage to increase towards the centre of a bole log.

Economic importance

A beehole is such a relatively small clean cut wound that apart from appearances and special uses, it affects the strength and quality of the wood very little. Moreover as beeholes are usually sealed up quickly by later growth there is rarely any accessory decay or deterioration in an otherwise sound tree; very rarely a beehole is filled up with a stony deposit that affects saws. Timber traders object strongly to beeholes on principle and therefore the market values of the higher grades of teak are seriously affected. Beeholes are inadmissible in first quality squares and for high class work. In those grades in which beeholes are permissible in small numbers other defects are also allowed; it is not practical to evaluate the loss in price caused by beeholes alone.

It is probable that the value of the annual outturn of teak in Burma is lessened by 10–15 percent by the attacks of the borer. If the beehole borer did not exist Government would receive about 10 lakhs of rupees additional revenue annually and the profits of the owners or buyers of the timber would increase at least to the same extent.

The complaints expressed by teak extraction agencies that beehole damage is far more prevalent in timber today than it was 20 or 30 years ago are not confirmed by statistical evidence; during a period of financial depression and slump in the timber trade there is a tendency for all defects in timber to acquire an unusual emphasis. Most of the beeholes in the heart of mature timber were made 100–150 years ago and recent events such as fire-protection, conservation, etc., cannot have affected their origin.

The depredations of *X. ceramica* have been claimed to be a vital argument against further planting of teak in Burma on the ground, amongst others, that such plantations cannot produce timber of the same quality as that produced in natural forest. It is now considered that the creation of plantations is still justified except in those districts where the beehole-incidence in natural forest is high. The regeneration policy can be adjusted satisfactorily to meet the variations in the menace from the pest, and

plantations in the zone of heavy incidence can be specially treated to prevent their abdandonment as a total loss. This subject is dealt with in detail under Control Measures in Part Two.

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Xyleutes persona is a beehole borer of *Cassia fistula*, *C. nodosa*, *C. renigera* and *C. siamea*. It is a larger moth than *X. ceramica* with a wing-span of 70–180 mm., the female of larger dimensions than the male; the head and abdomen are black, the thorax white; the forewing dark, its inner marginal area with large irregular conjoined white patches. The larva is dark flesh colour not definitely banded transversely. This species occurs in Ceylon, India, Burma and China.

The moths emerge irregularly throughout the year between February and October; the maximum abundance occurs in February, or April–May, or September–October, varying with locality.

The life of the moth extends to 16 days. A female may lay 60,000 eggs all of which usually hatch; a small fraction, less than 0·2 percent, of *unfertile* eggs may produce normal larvae. After hatching the larvae disperse and eventually settle on the living food-plant to bore tunnels in the wood which are more irregular than those of *X. ceramica* but as they grow larger *persona* larvae are more prone to abandon early tunnels and construct new ones elsewhere. The complete beehole is about the same size as that of *ceramica* but the walls are stained black and the sapwood-chamber is smaller. Pupation takes place at the upper end of the beehole behind a silk wad and the pupa travels down to the exit-hole and protrudes half its body to allow the moth to escape. The

life-cycle occupies from $1\frac{1}{2}$ to $2\frac{1}{2}$ years; the longest record is of an individual hatching from an egg laid in September and under observation till the moth emerged in March of the 3rd year.

The wounds made by the beeholes do not readily heal and repeated attacks seriously affect the vitality of the tree. The beehole-incidence of *persona* per tree is exceptionally high; the maximum record is 1,500 galleries in 3 years and this infestation was severe enough to kill the tree. In ornamental *Cassias* grown in gardens or avenues this borer is a bad pest. For control see Part Two.

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Zeuzera coffeae, The Red Borer.

This widespread species is a borer of the woody stems of young living saplings and the living branches of bushes of very many species. Among its food-plants are :—

Anona squamosa, Amherstia nobilis, Bauhinia malabarica, Cassia auriculata, C. fistula, C. grandis, C. siamea, Casuarina equisetifolia, Cedrela febrifuga, C. sinensis, C. toona, Cestrum nocturnum, Chikrassia tabularis, Cinnamomum zeylanicum, Citrus spp., *Clerodendron infortunatum, Coffea robusta, Eriobotrya japonica, Grevillea robusta, Hibiscus rosa-sinenis, Hydnocarpus wightiana, Lagerstroemia speciosa, Melia azedarach, Nephelium litchi, Persea gratissima, Phyllanthus emblica, Psidium guava, Santalum album, Schleichera trijuga, Swietenia macrophylla, S. mahagoni, Taraktogenus kurzii, Tectona grandis, Terminalia belerica, Thea sinensis, Theobroma cacao, Vitex pubescens, Xylia dolabriformis.*

Life-history: The reddish-yellow eggs are laid in strings on the bark of small stems or branches; woody seedlings are also subject to attack. The larvae hatch after about 10 days and spin a shelter-network of silk. A few days later they launch themselves on the breeze supported by silk filaments and are carried by the wind for considerable distances. Eventually some settle on suitable food-plants and bore in, usually entering at the junction between a leaf-stalk or twig and the main stem. There is considerable mortality in the young larval stages. The tunnels of young larvae in small branches or stems are cylindrical and run more or less straight up and down the centre, but those of older larvae are widened out into irregular cavities at intervals. The tunnel may be eaten away right into the cambium and bast zone so that only a thin shell of bark is left. Sometimes the cavities are ring-shaped and completely girdle the shoot which dies back at once; the side branches of older trees break off at the girdle. A well developed tunnel reaches an overall length of between one and two feet and may extend down to the root of a small plant; exceptionally a tunnel in a teak sapling may extend

for 4 feet. At various distances in its course circular holes are cut to the outer surface through which the borer ejects its frass and excrement, which is in the form of yellowish or reddish rounded pellets, usually gummy and adhering in small lumps to the bark or collecting in a heap on the ground below.

The full-grown larva is about 40 mm., long with a brown head and a brown, sclerotised, pronotal shield which is broader than long, curved on its anterior margin, and bearing on the posterior area several rows of small, backwardly directed asperities that are largest towards the middle line (very much as in *Xyleutes*). The first seven abdominal segments are pinkish to purplish-brown above (but sometimes reddish-brown or brick-red) and yellowish below; the 8th, 9th and 10th segments are brownish, the two last with smooth glossy plates.

Feeding by the larva goes on for 60 to 120 days in the tropics and for the greater part of the year in colder northern climates. When ready to pupate it cuts a circular aperture in the outer wall of the tunnel which is closed by a thin skin of bark not completely severed; then it spins a loose mesh of silk in the cavity that serves as a pupal chamber, blocks the end or ends with a plug of frass and pupates with the head towards the exit-hole, usually head downwards. The pupa is about 25 mm. long, chestnut brown, with a short blunt process above the eyes and with transverse rows of backwardly projecting asperities on the dorsal surface of the abdominal segments.

The pupal period lasts for 3 weeks to a month at the end of which time the pupa wriggles towards the exit-hole pushing out the door-flap and extending its body about half way through the hole. The moth emerges, leaving the empty pupal skin protruding from the hole in the bark; it takes about 20 minutes for the wings to expand and dry. The moth is white with pairs of small black dots on the thorax and numerous small black spots and streaks on the forewing and a few black spots on the hind edge of the hindwing; expanse, 35 to 45 mm. The female lays 500–1,000 eggs in 1–2 weeks.

The cycle of development of *Zeuzera coffeae* lasts 4–5 months in southern Indian regions and at low elevations, and probably extends to a year at high elevations and in the north of India. There are 2 generations a year in Burma. It is capable of breeding continuously all the year round and may be found in almost every stage of development in each month; there is therefore no marked seasonal sequence of generations.

Economic importance: This insect is a serious pest of tea and coffee growing areas in India and Ceylon where it is known as the Red Borer or the Coffee Borer. It is frequently a pest of yearlings and small saplings in forest tree nurseries, in yas and other artificial regeneration areas, particularly of *Casuarina equisetifolia*, *Santalum album*, *Swietenia macrophylla*, *Tectona*

grandis and *Xylia dolabriformis.* The attacked plants die back to the point at which they are girdled by the tunnel of the borer, or are killed outright if small. For control see Part Two.

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Zeuzera indica is a borer of the bole and branches of large dimensions of living *Litsaea polyantha.* The tunnel is of the beehole type and runs upwards for 10-15 inches from a chamber on the surface of the sapwood and penetrates to a depth of several inches in the wood. When the infestation is crowded two or more larvae may make tunnels from a common sapwood chamber, or a secondary branch-tunnel may start from an earlier beehole. The pupa descends the tunnel to its mouth in order to release the moth which emerges in August.

Zeuzera multistrigata is a borer of *Cryptomeria japonica, Mussaenda frondosa, Quercus lineata,* and *Santalum album* but occurs chiefly in the Himalayas. The moth emerges in August to September. Casualties in *Cryptomeria* plantations in Bengal necessitate the filling up of many vacancies.

Zeuzera postexcisa bores the trunk of *Phoebe excelsa* and possibly Magnoliaceae and Lauraceae.

Kalshoven L. G. E., 1919, *Meded. Proefst. Boschwezen*, No. 4, pp. 69-71, 1 pl., De roode stamboorder.

EPERMENIIDAE

Fletcher T. B., 1921, *Mem. Dept. Agr. Ind*, Ent., VI, pp. 169-170.

Epimarptis philocoma feeds on the surface of the leaves of *Butea frondosa* and *Xylia dolabriformis* under the protection of a web of silk and excrement.

Lasiostega siderina mines elongate blotches under the upper cuticle of the leaf of *Randia dumetorum,* and feeds in the cleared space formed by disposing of the excrement at one end of the blotch.

EPIPLEMIDAE

Hampson G. F., 1895, *Fauna Brit. Ind.*, Moths, III, pp. 121-137, figs. 66-75.

Dirades theclata frequently appears over large areas as a defoliator of *Adina cordifolia* from July or August sometimes continuing until October. It also feeds on *Randia dumetorum.* The larva is greyish and somewhat tuberculate. The leaf is eaten from the margins towards the midrib, but only superficially so that it appears coarsely skeletonised or perforated. Pupation takes place on the ground or on the dead leaf. The cocoon is covered with particles of soil or dust of the dry leaf. The moth

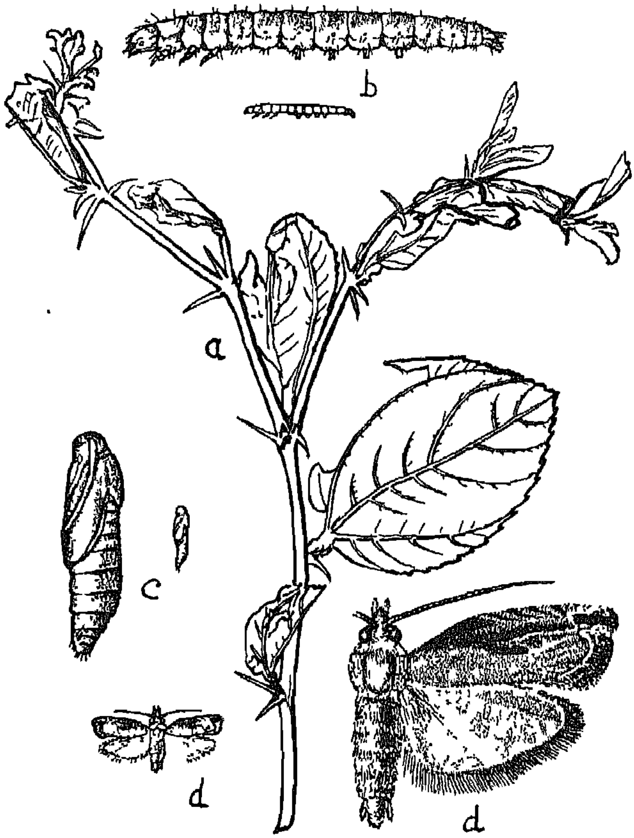

Fig. 164. Ancylis lutescens, Eucosmidae, and attacked shoot of Zizyphus jujuba, natural size.

is violaceous-grey with brown markings; expanse 3/4 of an inch. The main defoliation occurs in August and September when the life-cycle is about a month and has a pupal period of 5 or 6 days, towards the end of September the pupal period increases to 7 to 9 days.

EPIPYROPIDAE

Fletcher T. B., 1919, *Proc. Third Ent. Meet., Pusa*, III, p 979, Indian Epipyropidae

Epipyrops eurybrachidis. The caterpillar of this moth is an external parasite of the females of *Eurybrachys tomentosa* (Fulgoridae). The female moth lays about 400 eggs on the leaves of the foodplant of *Eurybrachys*. The caterpillar attaches itself to the abdomen of the host under the wing; it scrapes away the wax,

which covers the body of the bug in the form of cottony filaments, and feeds on the fatty tissues and the soft membraneous areas of the body. The larval period lasts 6-7 weeks and the mature larva, 8 mm. long, leaves the host to pupate in a cocoon spun on a leaf.

Krishnamurti B., 1933, *Journ. Bomb. Nat. Hist. Soc.*, xxxvi, pp. 944-948, pl., The biology and morphology of Epipyrops eurybrachidis.

Epipyrops melanoleuca. The caterpillar is an external parasite of *Pyrilla* spp., leaf-hoppers of sugarcane, and has been used for the biological control of these pests in the United Provinces, India.

EUCOSMIDAE

CATERPILLARS of this tortricoid family are leaf-eaters, leaf-rollers or webbers, fruit or pod-borers, flower or bud-eaters, root-borers, etc.

LITERATURE ON EUCOSMIDAE:

Fletcher T. B., 1920, *Mem. Dept. Agr. Ind.*, Ent., vi, pp. 43-68, 199-201, pls. viii, x-xv, lix-lxi, Life-histories of Indian insects, Microlepidoptera, Eucosmidae.

— 1932, *Imp Counc. Agr. Res., Sci. Mon.*, No. 2, pp. 18-37, pls. xi-xxv, *ibid.*

Acroclita cheradota feeds in the rolled leaves of *Ficus glomerata*, *F. religiosa*, and *F. rumphii*. **A. cryptolitha** feeds on the flowers of *Butea frondosa*. **A. notophthalma** defoliates *Artocarpus hirsuta*, *Casearia tomentosa* and *Saccopetalum tomentosum*. The larval feeding-period lasts over 6 weeks in November and the pupal period 2 to 3 weeks. **A. vigescens** webs together the leaves of *Cordia latifolia* and *C. myxa*, living inside and feeding on the leaf-surface. Fletcher, 1920, p. 44, p. 199, pl. viii, fig. 2.

Ancylis lutescens rolls or twists the leaves of *Zizyphus jujuba* and feeds on the epidermis of the upper surface of the rolled leaf; young tender leaves are eaten from the edge; it also bores in the fruits. The full-grown larva, 30 mm., with brown and light-green stripes along the back and sides, pupates in the rolled up chamber roofed in with silk. The moth has a wing-expanse of less than one inch [fig. 164]. Fletcher, 1920, *lit. cit.*, p. 45, p. 199, pl. lix.

Argyroploce albitibiana feeds on the foliage of *Miliusa velutina*. **A. aprobola** is a polyphagous species in India and Burma, the larva of which rolls the young leaves of and defoliates *Albizzia procera*, *Cassia tora*, *Lagerstroemia flos reginae*, *Lantana aculeata*, *Mangifera indica*, *Nephelium litchi*, *Polyalthia longifolia*, *Salix tetrasperma*, *Schleichera trijuga*, *Shorea robusta* and *Xylia dolabriformis*. The mature larva is 20 mm., the pupa 7-10 mm. It is common in India and Ceylon and Burma and widespread, Australia to the Seychelles. Fletcher, 1920, p. 57, p. 200. —1932, p. 27, pl. xviii. **A. camarotis** is a leaf-

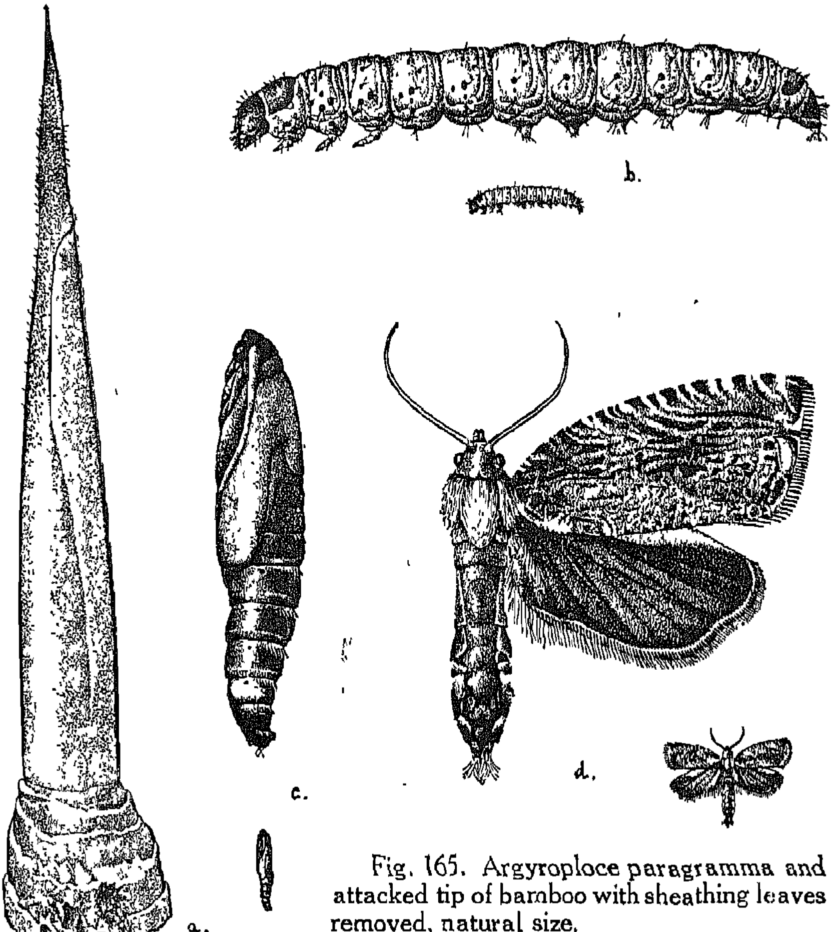

Fig. 165. Argyroploce paragramma and attacked tip of bamboo with sheathing leaves removed, natural size.

roller of *Michelia champaca*. Emergences of the moth occur in October–November and in April with a pupal period of 1 to 3 weeks. **A. cellifera** rolls and eats the leaves of *Eugenia jambolana* and pupates in the spun up leaf-roll. In the warm weather the pupal period is 5 days; in January–February it is 36–48 days. Fletcher, 1932, p. 25 pl. xvi, (Polychrosis cellifera).

Argyroploce illepida is a widely distributed species that feeds in the fruits of various forest trees. The full-grown larva is 15–20 mm. × 2–3 mm., yellow to reddish, marked with darker broken lines; pupa 8 mm.; moth wing-expanse 20 mm. The larvae are found boring in the long pods of *Cassia fistula* destroying the seeds and septa and ejecting the waste through holes in the side of the pod. Other food includes the pulp of the fruits of *Aegle*

marmelos and *Feronia elephantum*, the stalk and seeds of litchi fruits, the pods of *Acacia arabica*, *A. farnesiana*, *Bauhinia purpurea*, *Cassia occidentalis*, *Pithecolobium dulce*, and *Sesbania grandiflora*, and the fruits of *Tamarindus indica*. Pupation takes place in the attacked fruit or outside in a thin white silk cocoon. The pupal period is 7–14 days and the pupa partially emerges from the rind of the fruit before the moth escapes.

Fletcher T. B., 1920, *tit. cit.*, pp. 55-57, pl. xiii (moth). —1932, *tit. cit.*, p. 29, pl. xix (stages).

Argyroploce paragramma bores the growing culms of bamboo, *Dendrocalamus strictus*, in the rainy season. [fig. 165]. The young larvae at first feed at the bases of the free tips of the sheathing bracts and when older bore into the soft stem under the shelter of the bracts, usually at the leaf-buds. Pupation occurs in a thin cocoon between the bract and the node. The larva is brown in colour with numerous black tubercles; length 17 mm.; moth wing-expanse 20 mm. A heavy attack causes the death of the young culms. Fletcher, 1920, p. 160, pl. xiv, fig. 1.

Argyroploce threnodes rolls the leaves of *Michelia champaca*. **A. tonsoria** bores the fruits and the young shoots of *Barringtonia racemosa*.

Enarmonia amphilecta bores the shoots of *Cordia myxa*.

E. disperma feeds in the acorns of *Quercus incana*. **E. ethelinda** bores the cones of *Picea morinda*; the moths emerge in April, May. **E. heteropa** feeds on the leaves of *Butea frondosa*, and also bores in the young green shoots.

Enarmonia jaculatrix feeds on the leaves of *Dalbergia sissoo* by night, sheltering at intervals and hibernating in the bark. Pupation occurs in a fine silk cocoon in a rolled up or super-imposed leaves or under bark. The emergence of the first generation may be prolonged from March to July. The full-grown larva is pale yellow, 10 mm.; pupa, reddish-brown with 4 hooks on the anal segment, 5 mm.; moth dusky grey.

Beeson, 1938, *Ind. For. Rec.*, Ent., IV, No. 1, p.7.
Fletcher T. B., 1920, *tit. cit.* p. 64, (Laspeyresia). —1932, *tit. cit.* p. 33.

Enarmonia koenigiana feeds in the rolled or superimposed leaves of *Melia azadirachta*, and when young bores the tender topshoots. **E. malesana** bores the pods of *Cassia auriculata*, *C. corymbosa* and *Parkinsonia*. **E. palamedes** feeds on the seeds and flowers and leaves of *Bauhinia variegata* and *Hardwickia binata*. **E. pulverula** is a borer of the seeds of *Dipterocarpus pilosus*, *D turbinatus* and *Shorea robusta*. Its life-history at seasons when there are no fruits is not known, but it is probably passed as a root or shoot-borer. **E. pychnochroa** feeds in the hard red and black seeds of the climber, *Abrus precatorius*, which contain an acrid poison; also in the pods of *Sesbania grandiflora*. **E staphiditis** bores the shoots of *Bauhinia purpurea*. Fletcher, 1922, p. 35, pl. xxiii.

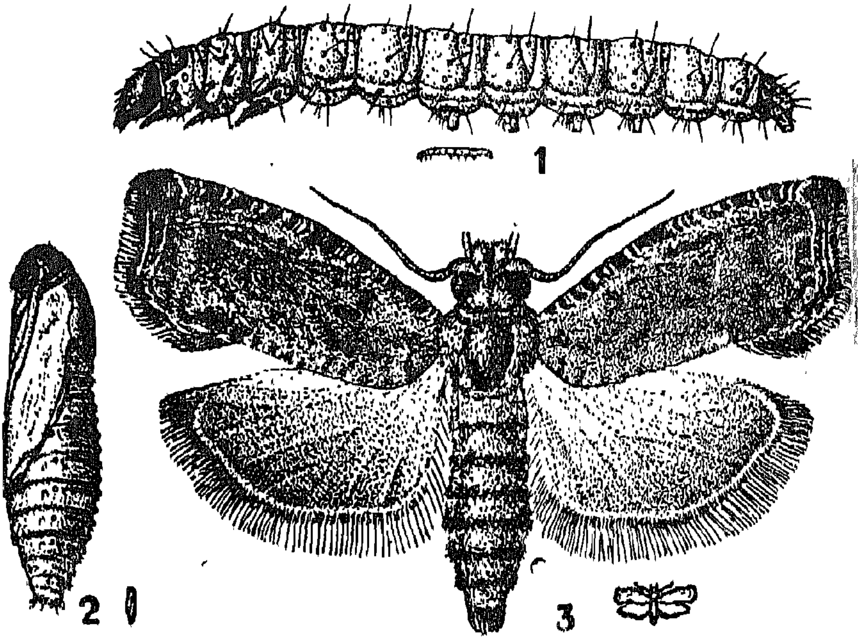

Fig. 166. Eucosma conciliata, enlarged and natural size.

Enarmonia stirpicola. Eggs are laid in the axil of the leaf-buds of *Butea frondosa* and the larvae bore in the pith of the shoot. They also feed on the buds and flowers of flowering shoots.

The mature larva, 11–12 mm. long, is creamy-yellow with small brown spots and a brown pronotal shield. Pupation occurs in a part of the tunnel lined with silk. The moth is dark grey with whitish speckling and black streaks; expanse 12–15 mm. The attack of this species on *Butea frondosa*, when pollarded or cultivated for lac, may be serious. The growth of the branches is checked, the bark is hardened and galled and an outflow of resin follows; the entrance-hole of the larva is often marked by granules of scarlet resin. The flowers are destroyed.

Fletcher T. B., 1932, *tit. cit.*, pp. 36, 37, pl. xxiv (previously Laspeyresia stirpicola).

Eucosma balanoptycha defoliates *Butea frondosa*, *Derris elliptica*, *Millettia auriculata* and *Pongamia glabra*; pupal period 6–8 days in the monsoon.

Eucosma conciliata [fig. 166]. The larva, 11 mm., bores into the thick parts at the base of the petals of *Butea frondosa* flowers, and also rolls and eats the young leaves. It also feeds on *Derris elliptica*.

Fletcher T. B., 1920, *tit cit.*, p. 50, pl. x, fig. 2. —1932, *tit. cit.*, p. 21, pls. xii, xiii.

Eucosma dryocarpa bores the acorns of *Quercus dilatata.*

E. hapalosarca defoliates *Populus euphratica* in the Punjab. **E. hilarocrossa** defoliates *Butea frondosa* in India and Burma; the pupal period is about a week in the monsoon.

Eucosma hypsidryas. The Spruce Budworm [fig. 167].

The female of this Spruce Budworm, [fig. 157, No. 22] lays its eggs on the young buds of spruce, *Picea morinda*, and one larva lives in each bud, feeding on the undeveloped needles inside but not harming those forming the outermost and lowest layer. These are spun together with silk and their tips remain enclosed in the bud-cap, so that a hollow spindle-shaped chamber is formed by the time the whole of the shoot within has been destroyed. In this chamber the larva, 15 mm., pupates. The damage is done in the spring months and the small moths emerge in June. There are presumably later broods during the rains before hibernation begins. The attacked spruces may be recognised by the brown aborted tips to the branches. Trees of all ages are attacked. The destruction of the buds prevent the normal annual formation of new shoots, so that the trees stagnate and the vitality is weakened to a degree at which bark-beetles (Scolytidae) and other borers (Cerambycidae) are able to attack fatally. The dying-off of spruce in the Himalayas is probably mainly due to the budworm.

Eucosma phoenocrossa feeds on *Careya arborea.* **E. stereoma** feeds in the rolled-up terminal leaves of *Acacia catechu* and *Pithecolobium dulce.* Larva greyish-yellow, 8 mm. **E. xerophloea** skeletonises and feeds on the leaves of *Populus euphratica* in July–September in the lower Indus valley.

Gypsonoma riparia skeletonises and webs together the leaves of *Populus euphratica* in the lower Indus valley during July to September. The pupal period is 4 or 5 days in July and 7 or 8 days in September.

Laspeyresia see **Enarmonia.**

Lobesia aelopa and **L. genialis.** The larvae web together the flowers and fruits of *Lantana aculeata* while feeding on them. The pulp of the fruit is eaten and the kernel is gnawed but the embryo is not damaged. Pupation (larva 9 mm.) occurs in a folded leaf. The total life-cycle takes about 4 weeks.

Beeson and Chatterjee N. C., 1940, *Ind. For. Rec.*, Ent., VI, No. 3, p. 58.
Fletcher T. B. 1920, *tit cit.*, pp. 54, 55, 200, pl. lxi, fig. 1.
Rao R., 1920, *Mem. Dept. Agr. Ind.*, V, p. 281.

Lobesia fetialis feeds on leaves of *Bucklandia populnea.*

Pammene theristis attacks the seeds, seedlings and young shoots of *Shorea robusta*; it also attacks *Pentacme suavis.* Eggs are laid on the ripe seed in which the larva feeds; moths mature from the seeds in July–September. Another generation bores in the young growing shoots of coppice or established regeneration of sal up to the sapling stage, killing back the leaders. Another generation attacks the young seedling completely hollowing out the taproot and part of the stem above ground so that it dies;

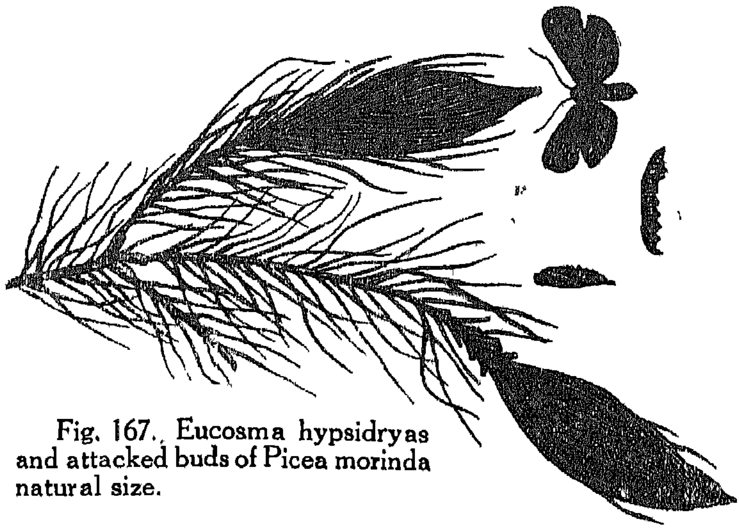

Fig. 167. Eucosma hypsidryas and attacked buds of Picea morinda natural size.

moths emerge from seedlings in the hot weather. There are probably more than 3 generations a year. The moth [fig. 157, No. 6] which is confusingly like that of *Enarmonia pulverula* has a wing-expanse of 15 mm. and is obscurely speckled with brown and dark blue and grey; the larva [fig. 156, No. 30] is whitish; the pupa has rows of small spines on the abdominal segments which enable it to travel up the tunnel before the moth escapes.

The economic importance of this species has not been thoroughly worked out and the interdependence of its several environments is not entirely established. Either as causation agent or as indicator it is closely connected with the dying off of new sal regeneration in the submontane belt of the United Provinces and in the Central Provinces, where often more than half of the young seedlings are killed by the root-boring generation.

Proschistis agitata defoliates *Eugenia jambolana* in the rains.

Stenolechia tricaspis mines the needles of *Pinus excelsa* in May and June in Kashmir.

Spilonota rhothia defoliates *Eugenia jambolana*, *Psidium guava* and *Woodfordia floribunda*, rolling tender leaves and eating holes. The larva is 10–14 mm. long and pupates in a flimsy cocoon in a turned over portion of the leaf. The pupal period is about one week in October. Fletcher, 1920, p. 43, 1932, p. 18, pl. xi.

EUPTEROTIDAE

CONTAINS hairy moths of large size, coloured in dull browns or yellows with dark markings, which are on the wing at the

beginning of the monsoon. [fig. 157, No. 10]. There are about 40 species in India. The caterpillars are clothed in long hairs and short bristles which are usually poisonous (urticating) and easily detached and cause considerable irritation to the human skin in which they get embedded. They feed at night and collect in closely packed colonies on the bark of trees during the day; often extensive epidemics occur. The life-cycle is annual with a pupal period prolonged through the cold and hot seasons.

LITERATURE ON EUPTEROTIDAE:

Mell R., 1929, *Deutsche Ent. Zeitschr.*, pp. 396–490, Die Brahmaeiden und Eupterotiden Chinas.

Hampson G. F., 1892, *Fauna Brit. Ind.*, Moths, I, pp. 41-65, figs. 24-38., Eupterotidae.

Eupterote fabia is a defoliator of *Erythrina indica* and *Michelia champaca* in Ceylon. The caterpillar is blackish, clothed with long grey hairs, and tufts of short urticating hairs, as in the following species; they feed at night and assemble in close packed masses on bark of trees during the day time. The moth resembles *E. undata.*

E. geminata defoliates *Gmelina arborea* and *Tectona grandis* during the wet season; other food-plants are *Cajanus indicus, Castilloa elastica, Erythrina indica, Hibiscus* spp. and crops such as tea, cocoa, cotton.

The eggs are laid in masses so as to form a tube encircling a twig. The younger caterpillars feed gregariously and assemble in clusters to moult; they frequently progress in long lines in single file. The older larvae usually scatter. In October the fullgrown individuals ($1\frac{1}{2}$ inches long) leave the tree and enter the soil for pupation at a depth of 1–2 inches without the formation of a definite cell. The mature larva is covered with long white or grey, black-tipped hairs in tufts, and also with tubercles bearing short stiff hairs. Laterally are yellow longitudinal stripes; at the caudal end is a brilliant reddish-yellow spot. The pupal stage lasts for 9 months throughout the winter and the dry season, and the moths commence to emerge when the monsoon has set in at the end of June and continue throughout July. The moth is orange-yellow with dark transverse bands; wing-expanse 60–80 mm. The generation is thus annual in north India.

In south India larvae feed from September to December or February (3 to 5 months) and have pupal periods of 2 to 3 months, producing moths about April. In Ceylon moths emerge in February from pupae formed in January (6 weeks pupal period). There are therefore 2 generations in the south.

E. testacea. Assam-China. The young larva feeds on grasses, dwarf bamboo and *Loropetalum chinense*; the older stages on various broad-leafed trees. In China the larval stage lasts about 125 days, May–September; pupation occurs in the soil, in a cocoon of hairs, silk and dust; the pupal stage lasts about 225 days and

the moth emerges in March–May; the generation is annual.

E. undata feeds on a large number of species of trees including *Bombax malabaricum*, *Careya arborea*, *Cedrela toona*, *Dalbergia volubilis*, *Erythrina indica*, *Gmelina arborea*, *Shorea robusta*, *Tecoma grandiflora*, *Tectona grandis*, *Terminalia* spp. and *Vitex negundo.*

Life-history: The sulphur-yellow eggs are laid on the underside of leaves in clusters of 250 to 300 at the beginning of the monsoon. The larvae feed gregariously mainly by night, and pack together during the day in closely crowded colonies on the bark or on the undersurface of large leaves. There are 8 moults during the larval life of $3\frac{1}{2}$ to 4 months and the last instar is about $2\frac{1}{2}$ inches long. The mature larva is black with a row of orange or ashy grey spots along the dorsal surface and a row of velvety black dots on each side, but the general colour appears to be brownish-grey owing to the presence of numerous long grey hairs and short, stiff, red-tipped hairs and tufts of short, brownish-yellow hairs all over the body. These short hairs arise from tubercles and are poisonous causing considerable irritation to the human skin in which they get embedded. In November (in north India) the caterpillars begin to pupate; a flimsy silk cocoon interspersed with larval hairs is sometimes constructed on a leaf and falls to the ground when the leaves are shed, but usually the larvae enter the soil directly for pupation forming a similar yellowish brown cocoon containing hairs and fragments of soil-debris. A period of about 8 months during the winter and hot weather is passed as a hibernating and aestivating pupa. The moths emerge in May–July; the wings are sulphur-yellow with dark markings. [fig. 157, No. 10]. The life-cycle is thus annual in regions with a cold season but in the extreme south a partial second generation occurs. When feeding on teak the whole tissue is eaten down to the main side-veins and midrib. Hard mature teak leaves are eaten by larvae of the third stage and older. This insect does not occur in young plantations, but is sometimes abundant in stands of trees of over 2 feet girth b.h. Owing to its habit of collecting in colonies on the bark it does not find a suitable environment in young pole woods.

1939, *Dept. Agr., Mysore. Circ.* No. 65, pp. 4, pl. 1, The Cardamom hairy caterpillar and its control in Mysore State.

Ganisa postica feeds on *Jasminum arborescens* and *J. latifolia.*

Pseudojana incandescens feeds on species of *Adina* and other woody Rubiaceae. The generation is annual with moths emerging in the premonsoon season, March–May.

GELECHIIDAE

DEFOLIATION by caterpillars of this very large microlepidopterous family is accomplished by rolling, webbing or spinning together the leaves and feeding within the shelter so formed; also by eating

buds. Shoots and seeds are bored and in some cases stem-galls are formed. Among cosmopolitan pests the family includes the Pink Bollworm of cotton, *Platyedra gossypiella* and the Potato Moth, *Phthorimaea operculella* and the Agoumois Grain Moth, *Sitotroga cerealella.*

LITERATURE ON GELECHIIDAE :
Fletcher T. B., 1920, *Mem. Dept. Agr. Ind.*, Ent., VI, pp. 69-95. p. 202-204, pls. xvi-xxi, lxii, Gelechiadae.
— 1932, *Imp. Counc. Agr. Res., Sci. Mon.*, No. 2, pp. 37-58, pls. xxvi-xxxv, Gelechiadae.

Anacampsis rivalis feeds in leaves of *Terminalia belerica* spun together.

Anarsia idioptila spins together the leaves of *Cassia fistula* and feeds on the leaves from within this shelter. Larva greenish-yellow about 7 mm. long. **A. melanchropa** feeds on the flowers and leaflets of *Acacia gageana.*

A. melanoplecta bores the buds and young shoots and feeds on the inflorescence of *Mangifera indica*; it is particularly a pest of newly planted mango grafts in plantations. **A. triglypta** feeds on the leaves of *Acacia catechu.*

Brachmia convolvuli feeds on several species of *Ipomaea*. **B. resoluta** feeds in the seeds of *Shorea robusta.*

Bucolarcha geodes feeds in the pods of *Acacia catechu.*

Coconympha iriarcha feeds on the leaves of *Cocos nucifera.*

Cymotricha antisticta spins together the young terminal leaves of *Terminalia tomentosa* for feeding and pupates in the same place. **C. metatoxa** defoliates *Bauhinia vahlii.*

Colbodes acanthopa rolls the leaves of *Eugenia jambolana,* pupating inside the leaf-roll

Desmophylax barymochla feeds on the leaves of *Helicteres isora.*

Dichomeris allantopa defoliates *Dalbergia sissoides*. **D. bisignella** defoliates *Mallotus philippinensis*. **D. crepitatrix** feeds on *Millettia auriculata.* January larvae produce moths in April after a pupal period of 25 days.

Dichomeris eridantis

Moth, [fig. 168, c], light fuscous with narrow oblong forewing, ashy or ochreous-grey slightly speckled with black, expanse two-thirds of an inch. Egg, dull white, elliptical, sculptured, 0.7 mm. Caterpillar, [fig. 168, a], smooth, slightly flattened, greenish-yellow, green or dark grey with two faint submedian lines, head and pronotum black, full size one inch. Pupa, dark brown, the anal segment with eight curved hairs, size 9 mm. × 2mm. The species is a minor pest of shisham particularly in irrigated plantations, and in the absence of the principal defoliator, *Plecoptera reflexa*, may be of local importance and destroy half the canopy in the season June to August. Probably found throughout India with *Dalbergia sissoo.*

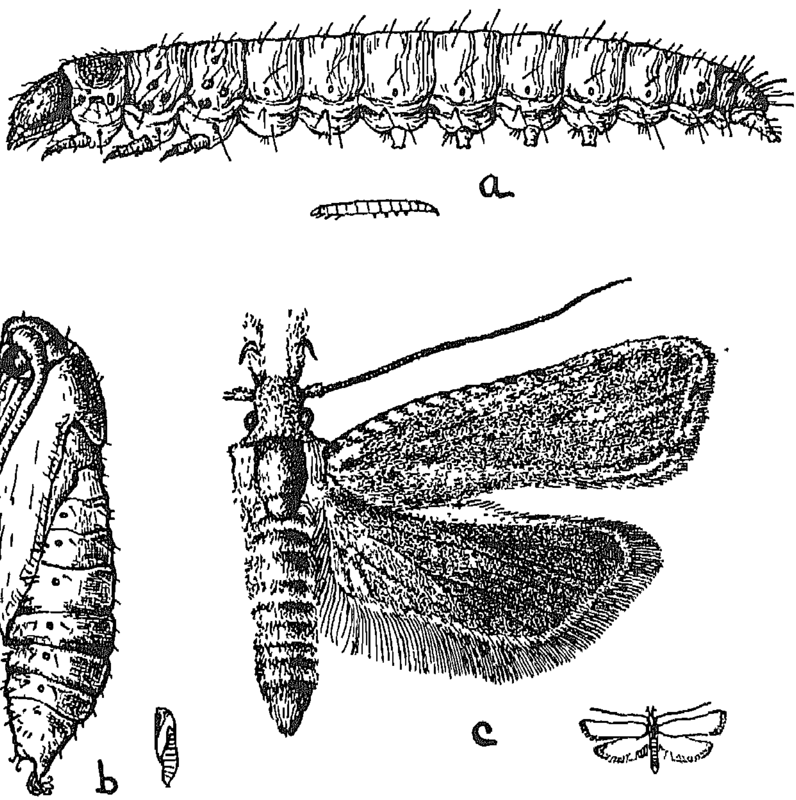

Fig. 168. Dichomeris eridantis, Gelechiidae

Life history: Eggs are laid usually singly, sometimes in twos and threes, on the underside of leaves. Hatching occurs after 2 or 3 days during May to September and 5 days in March and October. The caterpillar feeds on the leaves of shisham within shelters made by rolling a single leaf or more commonly by fastening together two leaves with silk. The inner leaf surface is abraded or small holes are eaten in the edges and blade, mainly at night. A shelter is often abandoned and a new one constructed, the caterpillar using a silk thread to move about the foliage. Both young and old leaves are attacked The larva moults four times and pupates in a white silk cocoon formed between two leaves on the tree or between dead leaves on the ground. The moth shelters in the soil vegetation during the day and becomes active at dusk.

There are 7 generations a year in northern India Between April and October the larval period ranges from 14 to 28 days and pupal period 5 to 10 days, the shortest periods in the hottest

weather. The incidence is light or moderate during April and May and damage becomes more conspicuous during June–August. The seventh generation caterpillars feed less actively as the cold weather approaches and then hibernate in their leaf-shelters for about 5 months, the total life-cycle of this generation taking 160 to 190 days. The moths of this generation emerge in March.

Beeson, 1938, *Ind. For. Rec.*, Ent., iv, No. 1, pp. 13, 14, Guide to the insects of Dalbergia sissoo.

Fletcher T. B., 1932, *Imp. Counc. Agr. Res.*, *Sci. Mon.*, No. 2, p. 52, pl. xxxiv.

Dichomeris petalodes feeds on the foliage of *Bridelia retusa*.

D. quercicola on the leaves of *Quercus incana*.

Epimastis glaucodes feeds on *Calophyllum inophyllum*.

Gaesa decusella feeds on *Croton oblongifolius* in south India.

Gelechia stenacma defoliates *Anogeissus latifolia*.

Gelechia tamariciella is a species associated with *Tamarix* spp. in India and the Mediterranean. The larva (about 7–8 mm.) feeds on the dry twigs binding 3 or 4 twigs to make a case in which it lives. Pupation occurs in a similar shelter.

Homaloxestis cholopis lives under the bark of dead logs of numerous species of trees in north India. The overwintering generation produces moths in April.

Hypatima polemica rolls the leaves of *Michelia champaca*.

H. scopulosa bores the shoot of *Careya arborea*. **H. spathota** folds and eats young leaves of *Lannea grandis*.

Istrianis crauropa feeds externally on the underside of the leaf of *Butea frondosa*.

Onebala hibisci defoliates *Hibiscus* spp. and *Urena lobata*.

Phthorimaea atomatina bores stems of *Tamarix dioica* making elongate fusiform galls, up to 1 inch long, with a large chamber and a circular exit-hole at one end.

Sitotroga cereallela is a cosmopolitan pest of grain of various kinds. Its eggs are parasitised by *Trichogramma evanescens* and are consequently sometimes used for the mass-production of parasites in biological control. In the forest it attacks bamboo seeds; the whole larval life is passed feeding inside the seed, one larva in each seed. The length of the life-cycle at its shortest is about one month with an egg-stage of 6 days and pupal stage of about 8 days. In the colder weather the life-cycle increases to 2 or 2½ months with hibernation as larva. Fletcher, 1920, pl. xvi figures the stages. The full-grown larva is about 1/5th of an inch and the moth about 1/4th of an inch long.

Stegasta variana feeds on the tied up leaves of *Cassia fistula* and other *Cassia* spp. Fletcher, 1920, *tit. cit.*, pl. lxii.

Symmoca anaphracta lives under the bark of dead logs in north India. The over-wintering generation produces moths in March, April.

Telphusa improvida feeds between overlapping spun up leaves

of *Lannea grandis.* **T. inferialis** defoliates *Shorea robusta* in June. **T. melanzona** mines the leaf of *Euphorbia neriifolia*, Fletcher, 1932, pl. xxix. **T. myricariella** feeds on the foliage of *Tamarix articulata* in the Punjab. When about to pupate the caterpillar enters the untenanted gall-like swellings on the twigs and branches of the tree that are made by another species. The pupal stage inside the gall-chamber lasts for 2 or 3 weeks in September–October. **T. platyphracta** feeds on the leaf of *Lannea grandis* under shelter of a flap or in the sewn up tip. **T. stegan-otricha** feeds on the foliage of *Desmodium* spp.

GEOMETRIDAE

GEOMETRIDAE form a dominant family of moths, almost always of slender build, and usually resting with wings widespread on a flat surface; females of some species have dwarfed or rudimentary wings. [fig. 157, No. 26]. Eggs are laid scattered or more rarely in a band on a twig. The larvae [fig. 156, No. 22] are characterisitic; the body is naked and slender with the suckerfeet or prolegs of the 3rd, 4th and 5th abdominal segments aborted or absent, so that there are only two functional pairs. The caterpillar progresses by curving the body in a vertical loop (so that the hinder part of the abdomen is brought near the thorax) and then again extending forwards to full length ; hence the caterpillars are known as "loopers". They are often coloured like green or dry twigs, which resemblance is increased when a twig is clasped by the hind prolegs and the body is held out stiffly at an angle. Pupation is commonly in the soil without constructing a silk cocoon.

Several species are liable to appear irregularly in epidemic proportions defoliating more or less pure forests, but in the rest of the species the caterpillars occur singly and are uncommon.

Identifications of recent collections have been done by L. B. Prout.

LITERATURE ON GEOMETRIDAE :

Beeson and Chatterjee N. C., 1940, *Ind. For. Rec.*, Ent., VI, No. 3, pp. 59-62, (Geometridae of lantana)

Hampson G. F., 1895, *Fauna Brit. Ind.*, Moths III, pp. 138-546, figs. 226, Geometridae.

Prout L. B., 1926. *Journ. Bomb. Nat. Hist. Soc.*, XXXI, pp. 129-146, 308-322, 780-799, 1 pl., On a collection of Geometridae from Upper Burma.

— 1926, *Mem. Dept. Agr., Ind.*, IX, pp. 247-257, New Indian Geometridae.

Agathia lycaenaria defoliates *Holarrhena antidysenterica* hibernating in the cold months as a pupa (pupal period 2 months) with moths in February. The form *A. lycaenaria discriminata* defoliates *Tabernaemontana heyneana*; the pupal period in May in south India is 8 days.

Antitrygodes cuneilinea defoliates *Adina cordifolia*, *Anthocephalus cadamba* and *Stephegyne diversifolia.*

Arorandria specularia feeds on *Acacia catechu* and *Terminalia paniculata*.

Ascotis infixaria feeds on *Dalbergia sissoo*, *Tectona grandis*, *Thuya orientalis* and *Xylia dolabriformis*. On sissoo and teak the ochreous black speckled larva, $1\frac{1}{4}$ inches, occurs from June–October. The pupal period is 2 weeks in October and 12 days in September, passed in the soil; the larval period is about 5 weeks.

Ascotis selenaria imparata. Moth, irrorated with dark brown on a whitish-grey or pale fuscous ground, abdomen with paired dark dorsal specks, expanse 2 inches. Caterpillar, a true looper with two pairs of sucker-feet on the last abdominal segments, naked, occurs in two colour forms, green with dark lines, or reddish-brown with darker lines and patches, full size 2 to 3 inches. When not feeding the caterpillar stretches out stiffly at an angle from a twig clasping it with the sucker-feet and so resembles a short shoot. Pupa, reddish-brown, naked, about 3/4rs of an inch. Distributed throughout India and beyond.

Life-history: Caterpillars from moths of the over-wintered generation occur early in the year and mature in April, with a pupal period of 7 to 9 days; from these, moths appear in May. Other generations occur during the monsoon, with a pupal period of 10 days in August–September, 11–13 days in October, and 19 days in November. Caterpillars that pupate in December overwinter as pupae in the soil and yield moths in February–March. There are five generations in northern India and six generations in southern India.

The species feeds on *Acacia farnesiana*, *Albizzia procera*, *Cannabis sativa*, *Dalbergia sissoo*, *Lantana aculeata*, *Melia azedarach*, *Phoebe lanceolata*, *Santalum album*, *Shorea robusta*, *Tectona grandis* and *Vitex negundo*. It causes wholesale defoliation of *Melia azedarach* in irrigated plantations of *Dalbergia sissoo* in the Punjab and also of the new flush of foliage of *Shorea robusta*.

Beeson, 1938, *Ind. For. Rec.*, Ent., IV, No. 1, p. 7, Guide to the insects of Dalbergia sissoo.
Chatterjee, N. C., 1935, *Ind. For. Rec.*, Ent., I, 10, p. 196.

Biston (Buzura) suppressaria. This widespread species is a general feeder, e.g., on *Acacia modesta*, *A. catechu*, *Aleurites montana*, *Bauhinia variegata*, *Cassia auriculata*, *Carissa diffusa*, *Dodonaea viscosa*, *Lagerstroemia indica* and tea bushes. There are apparently 3 generations in the year. Two generations and a partial third are possible in China where it is a serious pest of tung oil plantations. Eggs are laid on masses on bark and the larvae are dispersed by wind and crawling. The larva is described by Sevastopulo, D. G., 1939, *Journ. Bomb. Nat. Hist. Soc.*, XI, p. 691.

Boarmia acaciaria feeds on *Alseodaphne semecarpifolia*, *Cassia fistula*, *Dalbergia volubilis* and *Shorea robusta*. **B. fuligi-**

nea feeds on *Tectona grandis* in Burma; it also occurs in India. **B. trispinaria** feeds on *Eucalyptus* spp. and *Tectona grandis.*

Calicha minima feeds on *Elaeodendron glaucum.*

Chlorodontopera ocellata feeds on *Acacia caesia* and *A. concinna.*

Chrysocraspeda olearia defoliates *Eugenia jambolana.*

Cleora alienaria eats irregular and oval holes in the leaf of *Tectona grandis.* **C. cornaria** feeds on *Melia azadirachta* and *Tectona grandis.*

Cusiala raptaria defoliates *Acacia arabica* and *Shorea robusta.* The first generation appears in April from pupae overwintering in the soil. Caterpillars feeding in June and pupating at the beginning of the monsoon have a variable pupal period from 2 to 6 weeks.

Derambila saponaria defoliates *Vitex negundo.*

Dindica polyphaenaria defoliates *Alseodaphne owdenii.*

Diplodesma caudularia feeds on flowers and young leaves of *Lantana aculeata.*

Diplurodes shoreae defoliates *Shorea robusta.*

Dysphania bellona defoliates *Carallia lucida.*

Ectropis bhurmitra feeds on *Aleurites montana, Artemisia vulgaris, Bombax malabaricum, Lantana aculeata, Phoebe lanceolata, Shorea robusta* and *Tectona grandis.* The full-grown larva is greyish-green dotted with small brown dots, and has a darker lateral line and an incomplete mid dorsal line, but the colour-pattern is cryptic and very variable; length 1¼ inches. The life-cycle in the monsoon (July to October) is about a month including a pupal period of 10 or 11 days; Larvae pupating early in November have a pupal period of 30 days; larvae pupating in December overwinter as pupae for 50 to 60 days and yield moths in February.

Ectropis deodarae.

L i f e - h i s t o r y: The male moth [fig. 157, No. 25] has broad white wings with mottled black markings, but the female [fig. 157, No. 26] has the wings incompletely developed and is unable to fly. In order to lay eggs on the needles of deodar, its food-plant, she has to climb up the trunk of the tree. The green white-lined caterpillars [fig. 156, No. 22] hatch in March and feed until the end of the hot weather, completely denuding the tree of foliage. They descend from the crown of the tree by means of silk threads and pupate without forming cocoons under the layer of humus and fallen needles before the rains begin at the end of June. The rest of the year is passed in the pupal stage and the moths emerge in March of the following year. The life-cycle is thus annual.

E c o n o m i c i m p o r t a n c e: The pest is a defoliator of *Cedrus deodara* and is most injurious in the pure deodar forests of the outer ranges of the Himalayas of the United Provinces and

the Punjab. Epidemics occur at intervals of about ten years, e.g., in 1922, which caused complete defoliation for 2 or 3 years in succession and again in 1930 and in 1938. The defoliated trees put on a new crop of needles in July, but repeated defoliation may cause the death of as much as one third of the growing-stock particularly in the younger age-classes. A defoliated stand of young *Cedrus deodara* is shown in a later figure. The dying-off is assisted to some extent by bark-beetles (Scolytidae). For control see Part Two.

Beeson, 1925, *Ind. For.*, LI, pp. 560-572, 1 pl., The deodar defoliator.

Ectropis inceptaria feeds on *Lantana aculeata* flowers and leaves.

Gelasma goniaria defoliates *Terminalia tomentosa* and *Shorea robusta.* The pupal period is 9 days, in June.

Hemithea costipunctata occasionally feeds on the flowers of *Lantana aculeata.*

Hipparchus flavifrontaria defoliates *Quercus dilatata* and occasionally appears as a pest, e.g., in 1926–1928 in the forests near Muktesar, United Provinces. Continued defoliation is considered to prevent the formation of acorns and thereby affects the natural regeneration. The insect appears from April to early June and pupates at the beginning of May and the moths emerge 7 to 10 days after.

Hyposidra successaria and **H. talaca.** These two closely allied species occur together and feed on teak throughout India but do not appear in large numbers. The leaf may be eaten away steadily from the edge or feeding may take place at large isolated holes on the inner surface of the leaf. [see figure of teak defoliation in Part Two]. The young larva is black with a transverse white line on each segment of the abdomen; it passes through a stage of purplish ground-colour with orange dots and when mature is brownish-green to pale green with a group of three pink or orange dots on the side of each segment and fainter dorsal spots. The life-cycle is about 5 weeks in the monsoon (July to September) with a pupal period of 8 to 12 days which increases to 15 or more days in November; later in the year it becomes the hibernating stage and may last for 8 weeks. The pupa is naked.

The *successaria* form also feeds on *Acacia arabica*, *Barringtonia acutangula* and *Eugenia jambolana.*

The *talaca* form feeds on species of *Cassia*, *Dalbergia* and *Xylia* and on *Bombax malabaricum*, *Cedrela toona*, *Ficus glomerata*, *Holarrhena antidysenterica*, *Lantana aculeata*, *Siegesbeckia orientalis*, *Shorea robusta*, *Tectona grandis.*

Macaria fasciata feeds on *Acacia caesia* and *A. concinna.*

Orsonobia clelia feeds on *Alseodaphne semecarpifolia*, *Olea dioica*, and *Tectona grandis.*

Ozola microniaria defoliates *Premna barbata* and *P. latifolia*; pupal period 5–7 days in July.

Pingasa chlora and **P. ruginaria** defoliate *Xylia dolabriformis.*

Ptochophyle togata defoliates *Eugenia jambolana.*

Rhombarista devexata feeds on *Bauhinia variegata.*

Scopula actuaria feeds on the flowers and young leaves of *Lantana aculeata.*

Semiothisa emersaria feeds on *Cassia renigera* in Burma.

Semiothisa fidoniata is sometimes a pest of *Acacia catechu* in lac plantations, appearing at the end of the monsoon; pupation occurs in the soil. A generation of moths is produced as late as December.

Semiothisa pluviata defoliates young plants of species of *Albizzia.* The caterpillar is one inch long when full grown, variably coloured in grey or greenish with a yellow lateral stripe. The length of the larval stage is 3 to 4 weeks. Pupation occurs in the soil; the pupal stage lasts 2 to 3 weeks. Ths eggs are bright green and are laid singly or in clusters on the buds and young leaves and hatch in 5 to 6 days.

Semiothisa streniataria defoliates young plants of *Acacia arabica* in Sind in October; it also feeds on *Tamarix.*

Tephrina disputaria.

Life-history: The larva is of a dark grass-green colour with the anal segment lighter; in later stages the anal segment is dark green mottled with black; full grown length 1 inch. The young larvae feed on the newly formed and tender foliage of babul but as they grow in size the entire leaflets except the rachis and a few ragged shreds are devoured; when disturbed they drop by silk threads. The larval feeding-period during the months of July to September is 10 to 12 days. Pupation occurs in the soil 1–2 inches below ground, or between dry leaves on the surface; no cocoon is formed beyond a few strands of silk fastening the soil or particles of rubbish in position. The pupal period lasts 4 days in July, 5 days in August, and 7 days in September. The moth is marked with brown and white with a wing-expanse of one inch and shelters in the undergrowth or at the base of trees during the day becoming most active at dusk.

Economic importance: The species is an important defoliator of *Acacia arabica* where-ever the tree occurs. When abundant it completely strips the tree but even when there are small numbers which do not entirely consume the leaflets, the tree sheds its foliage.

Thalassodes immisaria feeds on the bud and foliage of *Mesua ferrea.*

Thalassodes quadraria feeds on *Calophyllum inophyllum, Polyalthia longifolia, Wagatea spicata* and *Xylia dolabriformis.*

Traminda mundissima defoliates *Acacia arabica.*

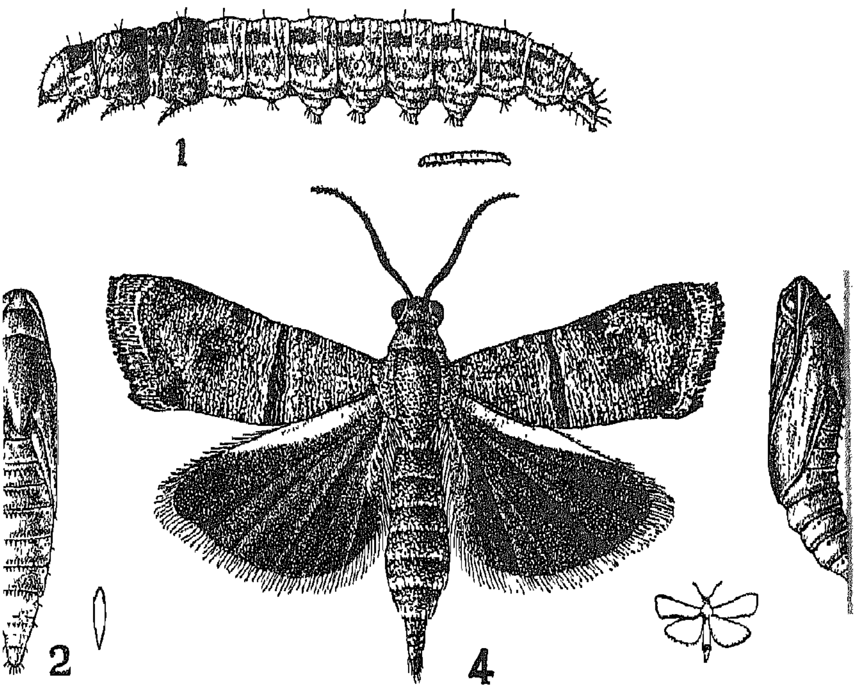

Fig. 169. Phycodes minor, Glyphipterygidae.

GLYPHIPTERYGIDAE

Fletcher T. B., 1921, *Mem. Dept. Agr. Ind.*, vi, pp. 123-128, pl. xxxi.
— 1933, *Imp. Counc. Agr. Res., Sci. Mon.* No. 4, pp. 23-26, pls. xxi-xxiv, Life-histories of Indian Microlepidoptera, Glyphipterygidae.

Anthophila aegyptiaca. The larva webs together and eats the young leaves of *Ficus infectoria* and *F. glomerata* and also feeds on the new aerial roots of *Ficus bengalensis* under shelter of silk webbing. Pupal period in June is about a week. Fletcher, 1933, *tit. cit.*, p. 24, pl. xxii.

Brenthia buthalis feeds on *Ficus gibbosa* and *F. glomerata* skeletonising the leaf; the pupal period is 10 days in March. **B. coronigera** defoliates *Cordia obliqua* and *C. myxa*. Fletcher, 1932, *tit. cit.*, p. 26, pl. xxiv,—1921, *tit. cit.*, p. 127, pl. xxxi.

Phycodes minor [fig. 169]. The larva feeds on *Ficus carica, F. cunia, F. heterophylla* and *F. palmata*, folding and binding the leaves together with profuse silk webbing. The larva is light green, the thorax dark, the abdomen with dark interrupted stripes; length 18 mm. Pupation occurs in a white cocoon amongst rolled leaves. Generations are active from May to November with a pupal period of 8 to 11 days.

Fletcher, 1932 *tit. cit.*, pp. 23, 24, pl. xxi.

Phycodes radiata rolls the young leaves of various species of *Ficus* and feeds on the epidermis; larva nearly one inch long, yellowish-white with a broad interrupted dark stripe along the side. A web is spun one or two days before pupation. The pupal period is 12-15 days in May-June.

GRACILARIADAE see LITHOCOLLETIDAE

HELIODINIDAE

Fletcher T. B., 1921, *Mem. Dept. Agr. Ind.*, vi, pp. 119-123, pl. xxviii-xxx (Heliodinidae).
— 1933, *Imp. Counc. Agr. Res., Sci. Mon.*, No. 4, pp. 20-23, pl. xviii-xx, Life-histories of Indian Microlepidoptera (Schreckensteinidae).

Hieromantis ioxysta rolls the edge of the leaf of *Schleichera trijuga* and feeds on the entire leaf-tissue from this shelter. The full grown larva, 9 mm., forms a transparent cocoon within an open meshwork of silk threads on the surface of the leaf. The pupal period is 4 days in April. It is sometimes a pest when *S. trijuga* is serving as a lac-host.

Fletcher, 1933, *tit. cit.*, p. 20, pl. xviii.

Oedematopoda clerodendronella feeds on *Clerodendron infortunatum* and *Anisomeles ovata*, and webs together the top of the shoot, eating holes in the leaves from within and pupates in a silk cocoon in the bunch of leaves. Larva about 10 mm. Moth with brick red forewings and thorax.

Fletcher, 1921, *tit. cit.*, p. 120, pl. xxix (coloured).

Statmopoda basiplectra bores into the pods of *Albizzia lebbek* eating the seeds; it also feeds on lac. Other species of **Stathmopoda** bore into the pods of Leguminoseae and in the fruits of *Ficus* spp. and other trees, some being gall-formers. Some are predaceous on Coccidae. Several species feed under dead bark of twigs and logs and have relatively long life-cycles.

HEPIALIDAE

THIS archaic family of Swift Moths is the only representative in the Oriental region of the suborder JUGATAE. Larvae of almost all forest species are borers of the stems of woody plants, usually the saplings of trees or shrubs, and have habits similar in detail to those described under *Phassus malabaricus*. The Indian species have recently been revised by N. B. Tindale who has separated several new forms and erected new genera in replacement of *Phassus*; as the publication of the revision has been postponed the current names are retained in this book.

Hampson G. F., 1892, *Fauna Brit. Ind.*, Moths, i, pp. 316-321, figs. 217-219, Hepialidae, (12 species).

Phassus auratus is a borer of young saplings of *Alnus nepalensis*, *Eucalyptus* sp. and *Cryptomeria japonica*, in the Bengal Himalayas. The moth emerges in August.

Phassus damor. A borer of living *Albizzia moluccana*, *Altingia excelsa*, *Cinchona* sp., *Eugenia* sp., *Erythrina* sp., *Evodia* sp., *Glochidion* sp., *Magnolia blumei*, *Nyssa javanica*, *Schima noronhae*, *Tectona grandis* in Java, not yet recorded from the Indian region.

Kalshoven, L. G., 1919, *Meded. v. h. Proefst. v. h. Boschwezen*, No. 4 pp. 75-81, pl. 21.

Phassus malabaricus, The Phassus Borer

The moth [fig. 157, No. 14] has the forewing greyish or brownish with obscure mottling along the inner and outer costal margins, the triangular area enclosed by these mottled bands more darkly coloured, the discoidal cell near its inner angle with a pale elongate marking and one or two pearly white dots; the hind-wing greyish Expanse of wings 2 to 4 inches. When at rest the moth hangs vertically, suspended by the long flattened hairy legs and resembles a shrivelled brown leaf.

Life-history: The moth is active for a short period at dusk. The eggs are produced in very large numbers (of the order of 40,000 in some Hepialidae) and are believed to be scattered broadcast by the female while in flight. The habits of the first stage caterpillars have not been observed but it is presumed that heavy mortality takes place before the successful caterpillars establish themselves by boring into living saplings. Usually the stem of a sapling is inhabited by only one caterpillar which bores into the centre and excavates a long cylindrical tunnel running axially downwards as far as the roots. The tunnel may reach a length of 2 feet and a diameter of 3/8ths of an inch and is slightly curved over at its top end like the handle of a walking-stick. Stems of the thickness of a cheroot to 5 inches diameter may be attacked. In older poles the tunnel runs in the sapwood and near the outer surface and is shorter—upto about 8 inches.

The tunnel is inhabited by the larva for nearly a year during which period it is gradually enlarged. It remains empty of wood-dust and its upper end opens into an extensive excavation or canker, formed by the continual browsing of the larva on the sapwood and on the callus that forms round the space eaten out in the bark and sapwood The callus-tissue and the sap flowing from the intersected vessels in the bast and wood forms the food of the larva which uses the tunnel only for shelter. The wound is covered over by a broad somewhat domed mat made of small particles of bark and wood, etc., spun together with silk—a large mat may be as big as the palm of one's hand and is always a conspicuous indication of the presence of the borer.

The full grown larva [fig. 156, No. 18] is cylindrical, about the thickness of a pencil, 3 inches long, and yellow with a black corrugated hemispherical head. It is able to move rapidly up and down the tunnel and retires to the lower part finally when ready

to pupate. A thick plug of interwoven brownish silk thread is spun to block the way while it is in the pupal stage.

The pupa possesses ridges and teeth-like asperities on the moveable abdominal segments by means of which it is able to wriggle its way up the tunnel and push through the mat. When half projecting the pupal skin splits and the moth emerges leaving the empty skin entangled in the mat. The pupal period lasts about 3 weeks and begins in April. The moths emerge mainly in May and on into June. The life-cycle is thus annual.

Food-plants: As is to be expected in so archaic a group of moths as the Hepialidae the species is polyphagous. The caterpillar develops in the following woody shrubs and saplings: *Acacia intsia*, *Abutilon crispum*, *Bridelia retusa*, *Callicarpa lanata*, *Cassia* spp., *Casuarina equisetifolia*, *Clerodendron infortunatum*, *Cordia myxa*, *Eucalyptus robusta*, and *E.* spp., *Filicium decipiens*, *Gmelina arborea*, *Grewia tiliaefolia*, *Gyrocarpus americanus*, *Lagerstroemia lanceolata*, *Lantana aculeata*, *L. indica*, *Macaranga indica*, *M. roxburghii*, *M. tomentosa*, *Mallotus philippinensis*, *Ocimum gratiosissimum*, *Rosa* spp., *Sapindus trifoliatus*, *Solanum torvum*, *S. verbascifolium*, *Strobilanthes callosus*, *Tectona grandis*, *Trema orientalis*, *Zizyphus horrida*.

This species occurs in south India and the Peninsula, Bombay, Coorg, Madras, from the sea coast up to 7,000 feet It is injurious in plantations of *Eucalyptus* and teak, which may be attacked at one year old; the site of the mat is usually between 3 inches and 3 feet above ground-level. Attacked stems may break off at the wound or may heal up according to the thickness and vigour of the plant and the extent of the girdling. For control see Part Two.

Phassus punctimargo. A borer of young *Cryptomeria japonica* in plantations in the Bengal Himalayas. The moth emerges in August. **P. purpurescens.** A borer of tea bushes in Ceylon. Phillips W. W. A., 1938, Spol. Zeylan., XXI, pp. 63, 64, pl. 1 (mating).

Phassus signifer. The moth is very similar to that of *P. malabaricus*, a little more richly coloured, the pearly spot at the inner aspect of the discoidal cell very small or absent, and the black spot near the base of the internal marginal band absent, expanse nearly 4 inches. The habits of the larva and the life-cycle are similar to those of *P. malabaricus*, which species *P. signifer* replaces in Assam and Burma as a borer of teak; it is possibly an undescribed species and not the true *signifer*. Emergence occurs in April–May and earlier. The moth, larva and external and internal aspects of the damage done by this borer in teak saplings are figured by Atkinson, 1931. Its food-plants are *Clerodendron infortunatum*, *Gmelina arborea*, *Tectona grandis*, possibly also *Terminalia myriocarpa*. For control see Part Two.

Atkinson, D. J., 1931, *Burma For. Bull.*, No. 26, Insect damage to the timber of teak. pp. 3, 4, pl i, figs. 2, 4,.iv, v, vi.

Phassus spp. (i). An unnamed species of *Phassus* attacks young living *Lagerstroemia flos-reginae* in Assam; the caterpillar girdles the stem by cutting away the bark in a horizontal band about ¼ of an inch wide, and makes a tunnel running vertically upwards in the centre of the stem, length 4 inches, diameter about ⅛ of an inch. The tree deposits considerable extra wood and produces a dense mass of adventitious roots above the girdle. The moth emerges in February or March. (ii). Another species attacks *Buettneria pilosa* in Burma. (iii). Another in *Gmelina arborea* in Burma emerging in May. (iv). Another in *Machilus edulis* in Bengal emerging in August. (v). Another in *Strobilanthes neesianus* in Bombay emerging in June.

HESPERIIDAE

Bell T. R. D., 1921-1927, *Journ. Bomb. Nat. Hist. Soc.*, XXVII, pp. 778-793, XXIX, pp. 429-455, XXX, pp. 132-150, 285-305, 561-586, 822-837, XXXI, pp. 323-351, 655-686, 950-974, The common butterflies of the plains of India.

Evans W. H., 1927, *The identification of Indian butterflies*, pp. 196-272, 291-299, pls. XXX-XXXII, Hesperiidae,—idem 2nd ed.

SKIPPER Butterflies of the Indian region amount to about 280 species some of which are pests in agriculture of monocotyledonous plants and of some dicotyledonous plants. Species associated with forests are :—

Badamia exclamationis occurs throughout India and extends to China and Australia; it feeds on *Anogeissus acuminata* and *Terminalia belerica*. The caterpillar is parasitised by 2 species of teak defoliator parasites.

Baoris cahira feeds on the shoots of bamboos, rolling them into a tube in which pupation occurs.

Calaenorrhinus ambareesa, C. area and **C. leucocera** on *Strobilanthes callosus*. **Cupitha purrea** on *Combretum ovalifolium*, *Ehretia laevis*, *Terminalia belerica* and *T. paniculata*. **Cuprona ransonnetti potiphera** defoliates *Helicteres isora* in India; the young larva cuts and folds small flaps in the leaf.

Gangara thyrsis feeds on various palms and canes.

Halpe spp. on *Ochlandra talboti*. **Hasora alexis** defoliates *Pongamia glabra*, folding the leaf into a flat tube. **H. badra** on *Derris uliginosa*. **H. chabrona** on *Millettia racemosa*. **Hyarotis adrastus** on *Phoenix acaulis*.

Ismene fergussoni on *Combretum extensum*. **I. mahintha** defoliates *Aporosa roxburghii* and *Drimycarpus racemosa* in Burma.

Matapa aria rolls leaves of *Bambusa arundinacea*, *Dendrocalamus strictus*, *Ochlandra talboti*, *Oxytenanthera* sp.

Suastus gremius feeds on various palms. **Tagiades obscurus** feeds on *Dioscorea wallichii*. **Telicota** spp. on bamboos.

HYBLAEIDAE

ORIGINALLY the genus *Hyblaea* was included in the Noctuidae; it is now recognised as a separate family allied to Pyralidae. The food-plants of two species are known—**Hyblaea firmamentum** on *Callicarpa macrophylla* (Assam to China) and *H. puera*, a defoliator of teak in Indo-Malaya.

Hampson G. F., 1894, *Fauna Brit. Ind.*, Moths II, pp. 371-373, fig. 204 (Noctuidae).

Hyblaea puera, The Teak Defoliator

H. puera is distributed from New Guinea throughout the Indo-Malayan Region, also in South Africa and the West Indies. In the Region of India-Ceylon-Java-Indo-China teak is its principal food-plant but it has several alternatives on which it thrives and can regularly breed; by natural orders they are Araliaceae: *Heptapleurum venulosum*. Bignoniaceae; *Bignonia megapotamica*, *Catalpa kaempferi*, *Dolichandrone stipulata*, *Heterophragma adenophyllum*, *H. roxburghii*, *H. sulfureum*, *Kigelia pinnata*, *Markhamia platycalyx*, *Millingtonia hortensis*, *Oroxylum indicum*, *Stereospermum chelenoides*, *S. suaveolens*, *Tecoma undulata*. Juglandaceae: *Engelhardtia spicata*. Oleaceae: *Schrebera swietenoides*. Verbenaceae: *Callicarpa arborea*, *C. macrophylla*, *Premna latifolia*, *P. pyramidata*, *Symphorema involucratum*, *Tectona grandis*, *Vitex agnus-castus*, *V. canescens*, *V. glabrata*, *V. negundo*, *V. peduncularis*, *V. pubescens*. Development on some of these species is compared with development on teak on p. 615.

Moth: [fig. 157, No. 21]. Head and thorax greyish to reddish-brown, the abdomen dark brown with orange segmental bands. Forewing in variable tones of greyish, purplish or reddish-brown with streaks and suffused bands of darker colours. Hindwing dark brown with a curved orange scarlet-edged band transversely across the middle (sometimes broken into patches), and a similar patch on the margin near the anal angle. Underside of wing black with orange bands, the costa and apex light brown with black specks; towards the anal angle the colour becomes orange and there are 2 black spots. Wing-expanse 21-40 mm. Larva: [fig. 156, No. 28]. The first instar larva, 2 mm., is greenish with a black head; the body-colour darkens in later instars to slaty or bluish-black with black specks bearing the setae; the under-surface is lighter or olive-green. The 4th and 5th instars vary in pattern, either wholly dark, almost black, or dark greyish-green with faint longitudinal lines, or black with a broad dorsal orange or ochraceous band from pronotum to the anal segment which is wholly orange, and lateral longitudinal white and black lines; under-surface pale or yellow; full size 1–1½ inches; 35 mm. with head-capsule 3 mm. Pupa: size variable 13–19 mm. × 5–6·5 mm. Egg: white, ovoid, 1 mm.

Life-history

Oviposition: Moths are inactive and concealed in dark shelters during daylight. By night they are active fliers and, it is inferred, tend to migrate considerable distances in epidemic outbreaks. Mating takes place at an age of 2 or 3 days and fertilised eggs are deposited a night or two later. They are laid singly sticking to the upper or lower side of a leaf, particularly on young, tender foliage. The longest recorded oviposition-period of one female is 12 days; a week is a normal period. The maximum number of eggs laid by one female is over 1,000; the average is between 500 and 600.

Larval habits: The newly hatched larva must have young soft leaf-tissue for its food; it eats away a shallow depression or trench on the surface of the leaf, protecting itself with some strands of silk; the first instar lasts 2–4 days. The 2nd instar lasts 1–3 days and feeds similarly at skeletonised surface-patches usually with a hole through which it can escape from one side of the leaf to the other. The 3rd instar larva cuts out a semi-circular or rectangular flap at the edge of the leaf and folds it over flat, fastening it with silk as so to form a shelter; when overcrowed these flaps are made in the middle of the leaf. On teak the feeding-pattern of this instar is largely skeletonisation in the older leaves and total consumption in the newly formed leaves. The 4th instar lasts 2–4 days and the 5th 3–8 days. Each day the larva makes a shelter by folding over a part of the leaf and spinning silk; it retreats from danger by bolting through a hole to the other side or by dropping on a silk thread. Both the last stages feed by eating all the tissue between the larger stiffer side-veins, so that only the bare ribs are left of a completely defoliated teak leaf. Fig. 170 shows the complete stripping between the veins of a teak leaf, which is generally considered characteristic of *H. puera*; but coarse skeletonisation and the turned-over flap are characteristic of the earlier stages. Terminal buds and green epidermis are attacked only under the compulsion of extreme hunger. See comparative diagram of feeding-patterns of teak defoliators given in Part Two, section *Hyblaea puera*.

Moulting takes place in the leaf-folds. A larva about to moult loses colour and stops feeding; after the skin is cast an hour or two is needed for hardening and pigmentation of the new body and several more hours are spent resting before feeding is resumed.

Pupation: The mature 5th instar larva pupates on the leaf in a triangular leaf-fold cut specially and strongly spun together; sometimes a naturally curved leaf or juxtaposed leaves, or several parts of eaten leaves entangled in silk, are utilised. When the foliage of a tree is completely stripped the larva drops by a thread to find other foliage or to descend to the ground to

pupate in the undergrowth or in the soil-cover. The sites of pupation of a large population of defoliators are thus likely to be irregularly dispersed, and the pupae are not uniformly exposed to the destructive factors of the environment or to direct remedial measures.

Life-cycles and generations

The length of each of the several stages in the life-cycle is determined primarily by the climatic conditions, particularly temperature, and secondarily, to a less extent, by the quality of the food. The effect of climatic factors on the length of the life-cycle has been worked out in field-insectaries at several places in India and Burma. Data are recorded in the following pages in the form of individual minima and maxima and of monthly modes; the theoretical sequence of generations per annum based on data for teak in south India, north India and Burma is presented in tabular form.

SOUTH INDIA: The ecology of *H. puera* in south India was studied at the F. R. I. insectary at Nilambur, Madras.

Egg: The period of incubation varies throughout the year from 2 to 4 days.

Larva: The larval period on *Tectona grandis* varies from 8 to 17 days (individual minimum and maximum); for the first half of the year the monthly mode is 10–12 days and for the latter half 12–15 days (see table).

Pupa: The pupal period varies from 5 to 13 days, the mode over the greater part of the year being 6 or 7 days without much increase of the average period in the so called cold season.

Moth and pre-oviposition: The maximum longevity of the moth has not been worked out; it is presumably of the same order as in Burma as there is no hibernation. The preoviposition-period varies from 2 to 4 days in the monthly means.

Life-cycle: The life-cycle from egg to emergence of the moth varies from 15 to 34 days (individual minimum and maximum) and from 18 in April to 27 days in August (monthly modes). The total life-cycle from egg to egg varies from 17 to 38 days (individuals) and from 20 to 30 days (monthly modes). Monthly variation of the stages in the life-cycle is given in detail in the following table which shows the seasonal sequence of generations through the year. Theoretically, it is possible for a series of 14 complete generations with a partial 15th to occur. The quickest development takes place in March–May and the slowest in the monsoon, July–September. Compare with conditions in Burma, page 613.

Theoretical sequence of generations of Hyblaea puera on Tectona grandis in an average year at Nilambur, Madras, India.

Days from January 1.	Month	Incubation	Larval period	Pupal period	Pre-oviposition	Generation	Total life-cycle	Days from January 1.
31	January	3	12	8	3	1	26	26
						2	24	50
59	February	3	10	7	3	3	22	72
90	March	2	10	6	3	4	21	93
120	April	2	10	6	3	5	21	114
						6	20	134
151	May	2	9-10	5-6	2	7	22	156
181	June	3	10-12	6-8	3	8	24	180
212	July	3	14	8	4	9	29	209
243	August	3	15	8-9	3	10	30	239
273	September	3	13	7-8	4	11	29	268
304	October	3	13	7-8	4	12	28	296
334	November	3	12	8	4	13	27	323
						14	27	350
365	December	3	12	8	4	15	partial	

NOTE: The sequence of generations is assumed to start with moths emerging on the 1st January and to continue without interruption during the leafless period (on adventitious foliage). Fourteen full generations are possible at the average rate of development in an average year and a fifteenth is partially completed by 31st December.

COORG

At Tithimatti in south Coorg development is slower than in other localities. Incubation takes 3 or 4 days in June and July. The pupal period lasts in May 8, June 7, July-October 11, November 12, December 13, January 15 days (monthly modes).

BOMBAY

At an insectary at Palghar, North Thana, Bombay, the monthly mode of the pupal period was found to be June 4–5, July 6, August 6, September 7, October 6 days. The individual range was from 3 to 12 days.

CENTRAL PROVINCES

In an insectary maintained at Rahatgaon, Hoshangabad, C. P., the development of *H. pucra* on teak in July, August and September was—Incubation 3, 3, 3; Larva 12, 12, 12; Pupa 5, 6, 7; Life-cycle 20, 21, 22 days respectively. This rate is nearly the same as at Dehra Dun and Pyinmana but quicker than in south India. The sequence of generations is undetermined and it is probably interrupted before the monsoon by a period of aestivation as well as by a prolonged period of leaflessness.

NORTH INDIA

Egg: The period of incubation at Dehra Dun, U. P., varies throughout the year from 2–4 days.

Larva: The individual larval period on teak varies from 8–26 days; the monthly mode from April–August is 10 or 11 days (see page 611) and is longest in November just before the hibernation season approaches.

Pupa: The pupal period varies from 4 to 25 days; the monthly mode being shortest in May and June with 5 days; 6 or 7 during the monsoon and lengthening in October to 10 and in November to about twice as much.

Moth: The climate at Dehra Dun during the winter is cold enough to produce a hibernation-period of about 3 months, which is passed in the imaginal stage. The maximum life recorded for a moth is 83 days, but it is known from circumstantial evidence that this period is exceeded. The pre-oviposition-period varies from 2 to 4 days, the monthly mode being 2 days for April–August The earliest eggs of the year are deposited towards the end of March.

Life-cycle: The life-cycle from egg to emergence of the moth varies from 14 to 47 days (individual minimum and maximum); and from 17 days in May to 26 days in October (monthly means), and to more than a month (41 days) in the period involving October, November, December. The total life-cycle, i. e., including the pre-oviposition period, ranges from 16 to 50 days (individuals) and from 19–30 (monthly modes) and to 45 days for the period involving the last two months. Monthly variation of the stages of the life-cycle is given in detail in the following table which shows the seasonal sequence of generations through the year. Theoretically a series of 10 complete generations is possible at the average rate of development with an 11th which may be wholly or partially completed before the end of December according to weather conditions.

Theoretical sequence of generations of Hyblaea puera on Tectona grandis in an average year at Dehra Dun, U. P., India.

Days from January 1.	Month	Incubation	Larval period	Pupal period	Pre-oviposition	Generation	Total life-cycle	Days from January 1.
31	January		Moth	hibernates		11	—	31
59	February		Moth	hibernates		11	—	59
90	March	4	—	—	4	11	—	82
120	April	2	11	7	3	1	25	107
						2	22	129
151	May	2	10	5	2	3	19	148
181	June	2	10	5	3	4	20	168
						5	20	189
212	July	2	11	6	3	6	22	210
						7	22	232
243	August	2	11	7	3	8	23	255
273	September	3	12	7	4	9	26	280
304	October	3	13	10	4	10	30	311
334	November	4	21	12-22	4	11	45	356
365	December		Moth	hibernates		11	—	365

NOTE: The sequence of generations is assumed to start with moths of the overwintered generation (11) becoming active on 23rd March and with larvae hatching on 1st April. Ten full generations are possible at the average rate of development in an average year and an eleventh may be wholly or partially completed before the end of December.

BURMA

The ecology of *H. puera* in Burma was studied at the Forest Entomologist's insectary in Pyinmana; life-history data for Burma apply primarily to that locality.

E g g : The period of incubation varies throughout the year from 2 to 4 days, the mode being 2 days; exceptionally in May and June hatching may occur within 24 hours. When the mean of the minimum monthly temperatures is over 70°F. the incubation is not more than 2 days. At a temperature of 50°F. eggs do not remain viable for more than 7 days.

L a r v a : The individual period varies from 8 to 22 days; for the greater part of the year the monthly mode is 11 or 12 days (see table) and is longest in January, February, the fifth larval stage being particularly prolonged.

P u p a : The pupal period varies from 4 to 11 days, the mode over the greater part of the year being 6 or 7 days with an abrupt prolongation to 9 or 10 days in December, January. In artificial temperatures of 45°–55°F. at Pyinmana the pupal period has been prolonged to 17 days and at Dehra Dun as long as 25 days has been recorded for the pupal period under natural conditions without any indication of hibernation.

M o t h : The maximum life recorded for the moth at Pyinmana is 111 days (male) and 48 days (female); the male at all seasons lives appreciably longer than the female. The average life of the moth is shortest in July, August, and longest in the Burma winter which is, however, not cold enough to induce hibernation.

P r e - o v i p o s i t i o n and o v i p o s i t i o n : In the insectary the pre-oviposition period of the female varies from 2–8 days. The oviposition period extends up to 12 days.

L i f e - c y c l e : The life-cycle from egg to emergence of the moth varies from 14 to 34 days (individual minimum and maximum) and from 18 in April to 30 days in January (monthly means). The total life-cycle from egg to egg, i.e., including the pre-oviposition period, varies from 16 to 42 days (individuals) and from 21 to 36 days (monthly means). Monthly variation of the stages of the life-cycle is given in detail in the following table which shows the seasonal sequence of generations through the year. Theoretically, the occurrence of a series of 14 complete generations with a partial 15th is possible. At the Pyinmana insectary *H. puera* has been bred continuously for two years during which period 27 generations were completed. There is no hibernation during the coldest season. If the following table for Burma in compared with that for south India (page 609) it will be seen that the shortest life-cycles characterise the months of May, June and September in Burma, but March, April in south India where the monsoon-season is cooler. Both localities may produce 14–15 generations per annum.

Theoretical sequence of generations of Hyblaea puera on Tectona grandis in an average year at Pyinmana, Burma.

Days from January 1	Month	Incubation	Larval period	Pupal period	Pre-oviposition	Generation	Total life-cycle	Days from January 1.
31	January	3	17	10	6	1	36	36
59	February	2	15	7	5	2	29	65
90	March	2	12	6	4	3	24	89
120	April	2	12	6	3	4	23	112
151	May	2	11	6	3	5	22	134
						6	22	156
181	June	2	11	6	2	7	21	177
212	July	2	11	7	3	8	23	200
243	August	2	11	7	3	9	23	223
						10	23	246
273	September	2	11	6	3	11	22	268
304	October	2	12	6	4	12	24	292
334	November	2	12	7	4	13	25	317
365	December	3	14	10	5	14	32	345
						15	partial	

NOTE The sequence of generations is assumed to start with moths emerging on the 1st January and to continue without interruption during the leafless period (on adventitious foliage). Fourteen full generations are possible at the average rate of development in an average year and a fifteenth is partially completed by 31st December.

Food-preference

A l t e r n a t i v e f o o d - p l a n t s The relative attractiveness of teak and other food-plants to *H. puera* is important in determining the distribution of a population that is less than the available food supply is able to support. It decides the extent to which

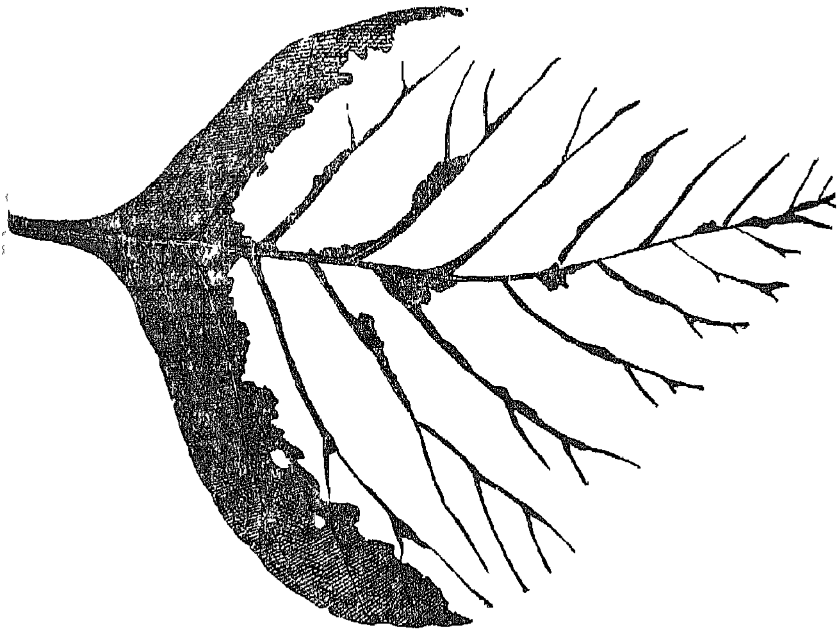

Fig. 170. Leaf of Tectona grandis eaten by Hyblaea puera, $\frac{1}{5}$th natural size.

From an early illustration of the work of the last instar larva. Other types of feeding-pattern produced by early instars are shown in the diagram in the section on H. puera in Part Two.

alternative food-plants can (i) absorb a part of the population of defoliators and divert it from teak, and (ii) provide breeding-material at a time when teak foliage is unsuitable or the tree is leafless.

(i) Experiments conducted at Dehra Dun with the 4 common food-plants *Tectona grandis*, *Vitex negundo*, *Premna latifolia* and *Callicarpa arborea* showed that, if the newly hatched larva is given the choice and equal facilities for reaching each of the 4 species, it displays no appreciable preference for any of the first three but is rather less attracted by *Callicarpa*. These conditions hold good for tender young foliage of each species. When the quality of the foliage is not uniform the preference is likely to be in the order—teak, *Vitex*, *Premna*, *Callicarpa*.

In Burma, experiments at Pyinmana indicated teak as the most preferred species out of 18; *Heterophragma adenophyllum*

and *Dolichandrone stipulata* are preferred to species of *Callicarpa, Premna, Stereospermum, Vitex*, etc.

(ii) It is evident from field observations in India that *Premna* and *Vitex* provide important sources of food for *H. puera* during the period teak leaves are aged and tough, or the tree is leafless; and in Burma *puera* feeds on teak mainly in May–July during the season of leaf-flush, subsisting largely on the numerous species of alternative food-plants in the autumn and spring, i.e., during the period of leaf-fall, November–March. It has also been demonstrated experimentally that moths oviposit on *Vitex negundo* or *Premna latifolia* and reject teak entirely when its foliage is unpalatable.

Quality of the food-supply: For the 1st instar larva the quality of the food is more important than the species; a very young larva must have soft young leaf-tissue of any species of food-plant and cannot survive on a diet of old leaf. Moths oviposit preferably on unexpanded teak leaves which have not entirely lost the reddish tinge. The older larvae thrive normally on fully expanded mature leaf. The species of the food-plant affects the rate of development and the incidental mortality. The larval period is longer on teak than on *Premna latifolia* and is shorter on *Vitex negundo* than on either—the difference between the extremes being about 12 percent. The percentage of survival to maturity is lowest on teak and highest on *Premna.*

There is no experimental indication of the existence of strains of *puera* exclusively associated with each plant-species; the progeny of parents descended from a line of generations reared on one species of food-plant will develop successfully on alternative food, and the rate of development will be that determined by the quality of the food and not by an ancestral character of the insect. Several cross-bred strains have been tested by mating a male reared on one species of plant with a female reared on another species of plant; their offspring fed readily on any other suitable food-plant without marked preference for the parental food. It is evident that *puera* habitually oscillates between its various food-plants, the moth selecting those that have foliage suitable for the nourishment of the young larva.

Incidence of defoliation

Seasonal abundance: The seasons at which *H. puera* is likely to be conspicuously abundant or epidemic in pure teak crops are decided by the climate of the locality, and the actual abundance reached in any one season is influenced by the local importance of alternative food-plants, natural enemies and disease. Everywhere in the season of mature foliage and leaf-fall the population-density drops annually to its lowest figure for the year. This annual return to a minimum population means that epidemics of *puera* do not build up gradually over a series of years

(as is usual for species with annual life-cycles) but that a gradation rises and falls entirely within one growing-season. In the dry hot season *puera* is scarce and may even aestivate in an extreme climate. In the west monsoon rainy season it increases in abundance provided the rainfall is within certain limits or periods but in regions of very heavy rainfall it does not multiply.

In south India at Nilambur the season of abundance is April to early June and there is sometimes a second phase in August–September. In Coorg teak plantations it increases in May, June and a second post-monsoon period of abundance culminates in October, and thereafter declines to a negligible degree in January.

In Bombay (Thana district) *puera* attacks begin with the rains and are at their height in July thereafter declining steadily. In the Central Provinces activity recommences with the onset of the monsoon after a period of minimum abundance and may be severe in July, August. In Dehra Dun it is most numerous on teak at the end of July and in September. In Burma the greatest abundance occurs in June and July, falling in the first half of August.

Although there are certain seasons in which the insect is frequently abundant the distribution of the population is not necessarily uniform or universal; on the contrary it is more characteristic for a pure teak stand to be heavily defoliated in small unconnected patches separated by areas in which caterpillars are scarce, and the sites of such patches change irregularly with successive broods. (Beeson, 1928, pl. 16).

Diameter-growth of teak stops between the beginning of October and mid-November (according to locality); heavy defoliation or complete stripping at this time of year has little effect on the current annual increment but may affect future height-growth and quality if buds are killed.

Crop-age: The incidence of defoliation in a pure teak crop is not uniform throughout the life of the stand from its formation to the end of the rotation. Incidence was measured from two aspects—intensity and frequency—over a five-year period in the Nilambur plantations.

The following conclusions apply to defoliation from all sources and not to *H. puera* alone. The frequency of light defoliation is high in stands of the age-class 1-10 years and rising considerably reaches its maximum in stands of 21–30 years old; thereafter the frequency falls rapidly and between 35 and 45 years has decreased to or fallen below its initial value. In the last half of the rotation of 80 years light defoliation is relatively less frequent than in the first half.

The frequency of general defoliation, i.e., of all grades combined, is highest in the age-classes 11–45; and the frequency of the severe grade of defoliation is also highest in these stands being at its maximum in the 21–30 class. In the 51 to over 70 age-

classes general defoliation is less frequent than in the younger crops, and in the same age-group severe defoliation is less than at any age except under 5 years. The severe incidence includes epidemic conditions, when stands of all ages are equally clean-stripped and there is therefore very little difference in the frequency of epidemics in each age-class; epidemics of clean stripping amount to only a small fraction of the time-period and do not affect the frequency of other grades.

A general falling-off in the intensity of defoliation from the age of 30 years, which becomes still more marked from the age of 50 years, must be largely due to improvement in control through natural enemies. The relatively low intensity of serious defoliation for the first 10 years, on the other hand, may be an effect of the quality of the food, as young teak matures its foliage more rapidly during the critical season.

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(see also section on Teak Defoliators, page 619).

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Economic importance of teak defoliators

It is not possible to isolate the economic importance of *Hyblaea puera* from that of *Hapalia machaeralis* and the many other defoliators of teak. Past records which go back 60 years *or more in Annual Reports or Plantation Journals, etc., rarely* discriminate the species involved; when 'skeletonisation' is mentioned it is often wrongly assigned to *machaeralis*, or, in some places it is fashionable to attribute everything to *puera*.

Observation plots maintained in teak stands with the intention of assessing the incidence of defoliation in grades such as Complete, Heavy and Light have not been very productive. Loss of increment and quality due to defoliation of teak must therefore *be considered in general terms;* the following information is not limited specifically to *puera* but covers all caterpillars, beetles, grasshoppers, etc.

F i n a n c i a l l o s s: INDIA: In the first quarter of this century the average annual loss in the Nilambur teak plantations was generally believed to amount to one third of the increment that should accrue (Minchin, 1929); this was probably the case during the worst period. Between 1926 and 1931 a continuous survey was maintained *over 5,000 acres of teak plantations and*

16,300 records were made of the monthly intensity of defoliation. This survey revealed that during an average growing-season of 10 months duration there is no defoliation at all for 54 percent of the time, light defoliation of no economic importance for 37 percent, and heavy defoliation including complete stripping for 9 percent of the time (2nd edition of data in Beeson, 1931). During this short period of heavy and complete defoliation the loss of increment is estimated (by Beeson) to be 13 percent of the normal current annual increment, and that during the rest of the year the loss is negligible. According to Champion, 1934, three complete strippings of a young teak crop in one season cause a loss of 65 percent of the normal increment and one stripping loses 30 percent. Hence, the severest epidemics of teak defoliators may cause a loss of Rs. 130 per acre in fully stocked first quality plantations. On the same basis the average annual incidence of 13 percent represents a loss of about Rs. 25 per acre in the same crops. In the poorest V and IV quality teak crops, where the royalty may not be more than 8 annas a cubic foot, a 10 percent decrease in the outturn represents a relatively small monetary loss; but such crops are of poor quality mainly because of the persistence of severe endemic defoliation which has already discounted their potential yield. A different standard of normality is needed to measure the effect of pests in them. Even if so low an average figure as Rs. 4½ per acre is applied throughout the 90,000 acres of teak plantations in India the loss is Rs. 4,00,000 per annum.

BURMA: Mackenzie, 1921, estimated the defoliation losses in the teak plantations of Burma on the basis of one complete stripping every 6 or 7 years at which the formation of half the annual increment is prevented. He put the total volume-increment lost as equivalent to that for 10 years in a 120 years rotation and for 5 years in a 75 years rotation, i.e., an annual loss of 8·3 percent or of 6·6 percent respectively. For the 110,000 acres of Burmese plantations this represents a total annual loss of Rs. 1,30,300 (for a 130-years rotation) or of Rs. 2,50,000 (for a 80-years rotation) at 3 percent C. I. These figures are much below those accepted today. The Burma forest entomologists have recorded cases in which a teak crop has depreciated from II to III class in 10 years with a loss of a quarter of the annual increment. Applying the figure of 13 percent of the current annual increment and an equivalent loss of Rs. 4½ per acre it is probable that the total annual loss for the existing teak plantations of Burma is nearly Rs. 5 lakhs.

L o s s i n q u a l i t y: Dying-back of the leading-shoot, forking, epicormic branches as well as total mortality are generally believed to be direct effects of defoliation. If a terminal bud is killed, forking usually results; if destruction of buds is coupled with injury to the epidermis of the shoot and delay in reflushing, it is

likely the shoot will die back. Buds may be gnawed or wholly destroyed by *puera* and *machaeralis* under the stimulus of hunger and when unsuitable foliage is the alternative. Epidermis is gnawed by caterpillars and grass-hoppers only in the total absence of leaf-tissue. Complete defoliation alone does not cause dying-back or death except in saplings that are otherwise unhealthy and weakened. The development of epicormic shoots is generally the result of unfavourable conditions; it is commonly associated with the drying up of the terminal shoots; there is frequently a flush of epicormics after heavy defoliation.

H. puera has not been incriminated experimentally or by observation as an agent of any of these defects.

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HYPONOMEUTIDAE see YPONOMEUTIDAE

HYPSIDAE

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Digama hearseyana feeds on *Carissa spinarum*; the pupal period is one week in May. The larva, 22 mm. long is characterised in Gardner, *tit. cit.*, pp. 293, 294.

The genus **Hypsa** contains several species that are defoliators of various species of *Ficus*. The larvae are sparsely hairy and the moths are conspicuously coloured with the forewing ochreous and the hindwing yellow. **Hypsa alciphron** feeds on *Broussonetia papyrifera, Ficus bengalensis, F. carica, F. cunia, F. gibbosa, F. glomerata, F. hispida, F. palmata, F. religiosa,* also on *Mesua ferrea,* and *Tectona grandis.* The full grown larva is about 1½ inches long, sparsely hairy with 3 velvety black and 4 yellowish - white longitudinal lines and transverse black bands on the 1st and 9th abdominal segments; the last segment is orange-red. Diagnostic characters are given in *tit cit.*, p. 293. The whole leaf except for remnants of the midrib and side veins is eaten. Pupation takes place in a curled up leaf. The incubation-period

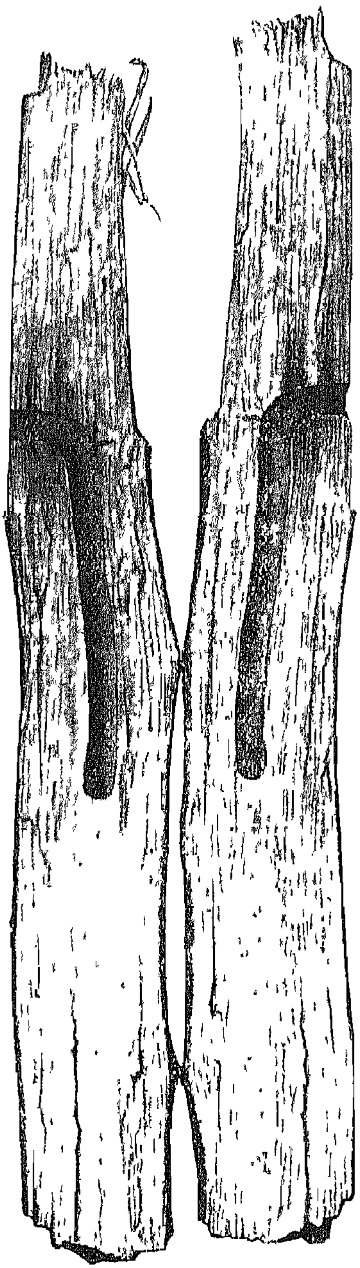


Fig. 171. Shelter-tunnel of Indarbela quadrinotata in stem of sapling of Casuarina equisetifolia, natural size.

for the egg is 5 days in April; the pupal period is 11 days in August. **Hypsa ficus** defoliates *Ficus glomerata*, *F. hispida*, *F. pumila*, *F. stipulata;* the pupal period is a fortnight in August and 3 weeks in October. It is also recorded from *Stephegyne diversifolia.* The larva, 40 mm., is characterised in *tit. cit.*, p. 293.

INDARBELIDAE

THE very small family of INDARBELIDAE includes species the larvae of which are known as Bark-eating caterpillars.

Hampson G. F., 1892, *Fauna Brit. Ind*, Moths I, pp. 314-316, figs 215, 216, Arbelidae.

Indarbela quadrinotata [fig. 171].

Life-history: In the genus **Indarbela** the eggs are laid in clusters of 15 to 20 directly on the bark of branch or bole; the larva bores a short tunnel downwards into the wood, usually at the junction of a dead branch or snag and the bole. This is used as a shelter-tunnel during the day and from it the larva issues at night to feed upon the outer surface of the bark, excavating broad irregular patches and paths that often extend several feet from the shelter-tunnel. These areas are roofed in with silk and fragments of bark and excrement; in extensive attacks the whole trunk of the tree may be covered with interlacing tracks involving the destruction of the greater part of the outer layers of bark. The full-grown larva [fig. 156, No. 16] is $1\frac{1}{2}$ to 2 inches long, smooth-skinned with dark chitinised patches on

the segments. Pupation takes place in the tunnel in the wood [fig. 171]; the pupa possesses rows of teeth or hooks on the abdominal segments by means of which it climbs out of the larval tunnel to release the moth. The pupal period lasts about 3 weeks. The life-cycle in India is annual with moths in May–July and the larval feeding-period is from June to April. In Burma there are two periods of emergence, viz., in March, April (majority) after pupation in February, March, and at the end of the monsoon in October, November. The moth [fig. 157, No. 35] has the fore-wing with rows of dark rusty red spots; in the subspecies **tetraonis** there are more intense spots before the margin and at the margin of the forewing. Expanse 35–50 mm. Longevity is only a few days but the female may lay nearly 2,000 eggs.

Economic importance: Numerous species of trees are attacked, e.g., *Acacia*, *Albizzia*, *Anogeissus*, *Bassia*, *Bauhinia*, *Berrya*, *Bombax*, *Boswellia*, *Callicarpa*, *Cassia*, *Casuarina*, *Cratoxylon*, *Eugenia*, *Gmelina*, *Grewia*, *Kydia*, *Lagerstroemia*, *Mallotus*, *Mangifera*, *Millettia*, *Mitragyna*, *Moringa*, *Phyllanthus*, *Psidium*, *Shorea*, *Stephegyne*, *Strychnos*, *Tectona*, *Terminalia*, *Woodfordia*, *Xylia*, *Zizyphus* including timber trees and fruit trees as well as many that are worthless silviculturally. The bark-eating caterpillars are of greatest importance in casuarina plantations in the Madras, Orissa and Bombay Presidencies. The damage comprises loss of increment due to destruction of the bark, and defects in the timber due to the shelter-tunnels (which are similar to beeholes), and to the rot which spreads from the dead snags. Excessive number of tunnels in teak ballies causes their rejection.

Extensive outbreaks of bark-eating caterpillars should be regarded as indicating an unhealthy condition in the crop and production of excessive quantities of dead branchlets or leaders, such as may be caused by drought, frost, fire, congestion, etc. For control see Part Two.

Iyer V. S., 1912, *For. Bull.*, No. 11, pls. i-iii (Arbela tetraones).

Indarbela campbelli occurs on *Ochna squamosa*. **I. dea** occurs on *Erythroxylon coca*. **I. theivora** occurs on *Mangifera indica* and tea.

LASIOCAMPIDAE

LASIOCAMPIDAE or Eggar-Moths are moderate to large-sized heavy-bodied moths with hairy caterpillars coated with short thick pubescence and with fringes or shaving-brush tufts of hairs which are often irritating to the human skin. The cocoon is a tightly woven tough bag. On account of the large size of the caterpillars local defoliation by relatively small numbers is serious but extensive epidemics over large areas are rare.

Hampson G. F., 1892, *Fauna Brit. Ind.*, Moths, I, pp. 402-430, figs. 278-298, Lasiocampidae.

Fletcher T. B., 1925, *Catalogue Ind. Ins.*, Part 7—Lasiocampidae.

Bhima undulosa feeds on *Quercus incana*; the larval period during the hot weather and monsoon lasts several months and the pupal period about 7 weeks. At lower elevations moths emerge in December; at higher elevations the life-cycle is annual.

Chilena similis is a defoliator of *Acacia catechu*. The caterpillars feeding during the monsoon-season pupate in August and produce moths in September, October. The second generation pupates in November making elongate cocoons of tough brownish-white silk in which the pupa rests throughout the cold and dry seasons for 7 or 8 months and the moths emerge in June.

Cosmotriche laeta feeds on *Dalbergia latifolia* and *D. sissoo*. The spindle-shaped cocoon is formed of tough buff or yellow silk sheet, aligned along a twig or grass-stem; moths occur in March from pupations in January, again in June and September–November.

Cosmotriche inobtrusa feeds on *Quercus incana*; the tough silk cocoon is like that of *C. laeta* formed along a twig.

Malacosoma indica. Defoliation occurs from April to early June; the pupal period is 7 to 9 days with moths emerging in May and June. The rest of the annual life-cycle is passed as a dormant egg laid in rings or bands on twigs and hatching in March, April. The species is a pest of *Quercus dilatata*, that also feeds on *Q. incana*; serious defoliation prevents the setting of the acorns and hence affects the regeneration, as for example in the Muktesar forests, U. P., where an outbreak occured in 1926–1928. For control measures see Part Two.

Metanastria aconyta feeds on *Lagerstroemia hypoleuca*.

Metanastria ampla occasionally defoliates *Shorea robusta* and also feeds on *Artemisia* in India; it is an important pest of forest trees, particularly oaks, in China. The caterpillars occur singly scattered over the foliage of the tree. The leaf is eaten from one side until entirely consumed. The full grown caterpillar, about 3 inches long, is speckled with minute black dots on a greyish-blue ground; at the sides of the first 6 abdominal segments and down the dorsal line are patches of yellow; the third thoracic segment has a red lateral patch. There is a conical brush of yellow hair on the dorsal surface of the third thoracic segment and smaller sparser tufts of yellow hair with long black setae on the remaining thoracic and abdominal segments except the fifth on which the hairs are white. Pupation occurs in a cocoon of tough dark brown silk about 2 inches long.

There are 2 generations a year in north India with moths appearing in May, June and in October, November. The larval feeding-period is about $2\frac{1}{2}$ months in the rains with a cocoon-period of 3 weeks, and 6 to 7 months with a cocoon-period of 3 or 4 weeks. Feeding continues through the winter; there are eight moults. In China there is 1 generation a year. The female

lays about 400 eggs singly on the food-plant in the autumn; these do not hatch until the second half of March or early April (at temperatures about 15°C.) The larva feeds until September or about 170 days and pupates in a cocoon in a sheltered place. Adults emerge during late October and November.

Metanastria grisea defoliates *Eugenia jambolana* and *Pinus khasya*.

Metanastria hyrtaca. Eggs are laid in groups or rows on leaves and twigs. The larva is covered with a close grey pubescence and a fringe of longer hairs at the sides and tufts on the mesonotum projecting forward on either side of the head; between the thorax and abdomen is a velvety black band bordering a patch of dark reddish hairs, which is exposed when the insect is alarmed; full size 3–4 inches. The larvae congregate in colonies before pupating. The cocoon resembles that of *Suana concolor*. The female moth is marked with transverse bands of light and dark brown on the forewing; the male has a chocolate-brown spot with a white centre on the forewing; expanse 2–4 inches. (Subramaniam T. V. and Anantanarayanan K. P., 1938). In north India there is a rains brood with a larval feeding-period of 6–8 weeks, a pupal period of 2–3 weeks and moths in October; hence two or more generations occur in the year. In south India the life-cycle takes 75–110 days (egg 9–12 days, larva 45–100 days, pupa 9–18 days).

The food-plants are many including *Acacia arabica*, *Albizzia stipulata*, *Anthocephalus cadamba*, *Bassia longifolia*, *Bischofia javanica*, *Eugenia jambolana*, *Eucalyptus globulus* and *E.* spp., *Mimusops elengi*, *Nyctanthes arbortristis*, *Schima wallichii*, *Terminalia* spp.

Subramanian T. V. and Anantanarayanan K. P., 1938, *Journ. Bomb. Nat. Hist. Soc.*, XL, pp. 257-263, pl., figs. 1-9.

Metanastria latipennis defoliates *Eucalyptus*, *Mesua ferrea*, *Shorea robusta* and *Woodfordia floribunda*.

Lebeda nobilis. *Pinus khasya* is subject to defoliation by the large caterpillars of 3 species of Lasiocampidae, *Metanastria ampla*, *M. grisea* and *Lebeda nobilis*. Defoliation commences at the beginning of the rains in the crowns of large trees. When these are completely defoliated the attack spreads to the young saplings and seedlings. The caterpillars when full grown are 4 inches long ; the body is clothed with a dense pubescence and with tufts of erect hairs. Pupation takes place in the undergrowth or in rolled up leaves in a tough cocoon. The moths emerge in August after a pupal period of 2–3 weeks and a second brood follows during the latter part of the rains with the next generation of moths in October and November. The moths have a wing-expanse of 4 inches are coloured in various shades of brown. *Lebeda nobilis* also feeds on *Myrica rubra*, *Quercus* spp. and *Thysanolaena agrostis*. In China there is one generation a year

with hibernation as an egg for 180 days or more. The larval stage lasts 140 days; the pupal stage 30 days.

Suana concolor. The moths appear in March–April; the colour is mainly reddish-brown with a wing-expanse of 2½ inches in the male and 4 inches in the female. The eggs are laid in patches around small twigs, as many as 650 by one female. The larva hatches after a fortnight and feeds throughout the hot weather becoming mature at the end of May and beginning of June. There are 6 or 7 larval instars in a larval life of about 65 days. The full grown caterpillar is about 4 inches long with a dense grey-brown pubescence with darker streaks and 2 bands of black hairs on the thorax (these hairs are barbed and liable to cause great irritation to the human skin); the segments are fringed with much longer hairs. It pupates 2 or 3 days after making a tough cocoon of silk interwoven with the urticating hairs, and placed in bark-crevices or tightly attached to branches. The pupal stage lasts 13 to 18 days in June. In north India the 2 generations are passed as described, but in the south 2 generations may occur at different seasons; the first is completed in September and the second in February–March. The second brood has the egg-period of 2 weeks, the larval period of 4–4½ months and the pupal period one month. The species is responsible for steady annual defoliation of *Shorea robusta* but does not appear to increase to very large numbers with the epidemics of other sal defoliators. Among its other food-plants are camphor, *Camellia thea*, *Cassia renigera*, *Embelia robusta*, *Eugenia jambolana* and *Eucalyptus*, *Litsaea polyantha*, *Psidium guava*, and *Tectona grandis.*

Syrastrena minor feeds on *Shorea robusta.*

Taragama dorsalis defoliates *Albizzia* sp., *Butea frondosa*, *Cassia renigera*, *Erythrina lithosperma*, *Zizyphus jujuba* and rubber and cocoa. The large brown-spotted eggs are laid in masses on branches and hatch in about 12 days. The caterpillars are full grown in 5 to 6 weeks and during the last 2 weeks eat large quantities of food. The toughly woven cocoon is attached along a twig and the pupal stage lasts 2 to 3 weeks. The total life-cycle is 8 to 9 weeks.

Hutson J.C., 1932, *Trop. Agric.*, LXXVIII, p. 131, pl. ii; — 1925, *tit. cit.*, LXIV, pp. 27-32. pl. 1-5.

Taragama siva [fig. 172]. The moths appear in May; the wings are pale brown and creamy with an expanse of nearly 3 inches. The eggs are laid in clusters or rows on twigs. The larva feeds for about a month and when full grown is 2 to 3 inches long and in colour greyish-brown with faint violet spots; there are tufts of long hairs at the sides of each segment. Under provocation short bands of black, blue-violet and white hairs are displayed on the thorax. Pupation occurs in an elongated papery cocoon interwoven with larval hairs and fastened along a twig.

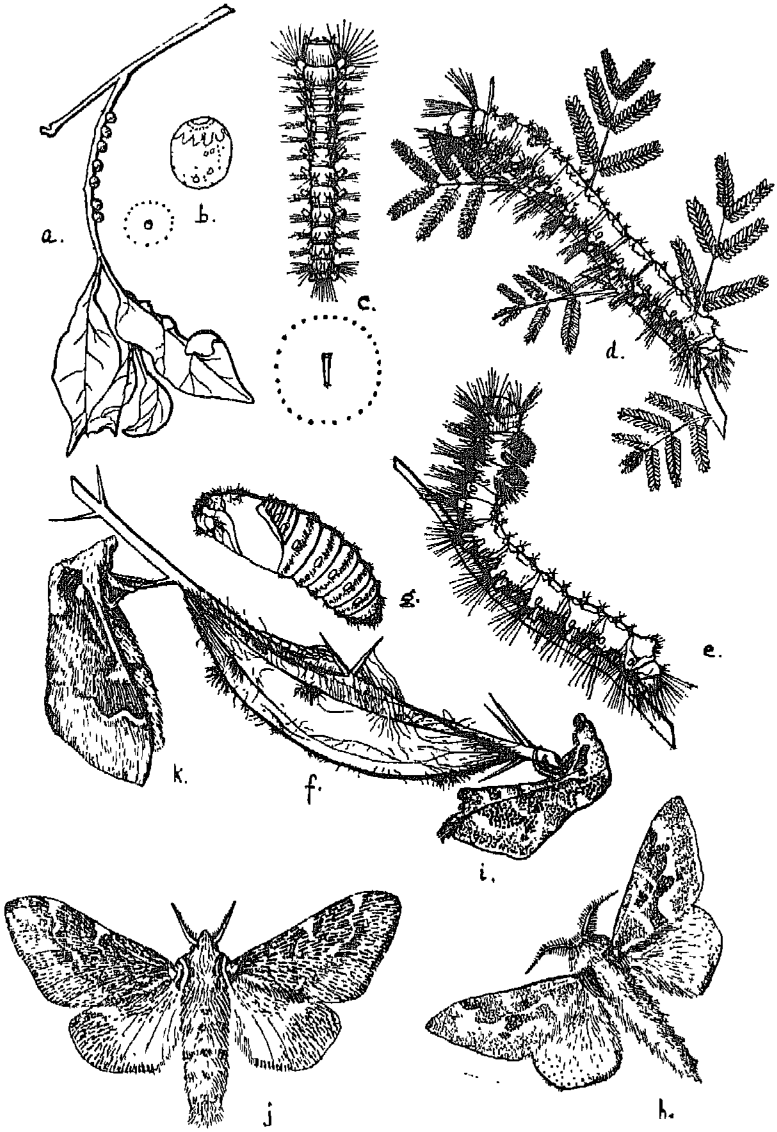


Fig. 172. Taragama siva on Acacia arabica, natural size.
a, *b*, eggs laid on twig; *c*, *d*, *e*, larva; *f*, cocoon; *g*, pupa;
h, *i*, male; *j*, *k*, female.

The moths emerge in July. After a life-cycle of about 6 weeks another brood emerges in September. In south India the cold weather brood may develop in 9 weeks. The species feeds on *Acacia arabica*, Mahogany, *Murraya exotica*, *Polyalthia longifolia*, *Tamarix gallica*, *T. indica*, *Zizyphus jujuba*.

Fletcher T. B., 1919, *Agr. Res. Inst.*, Bull. 89, pp. 68-71, fig. 40.

Trabala vishnou. Life-history: The leaden grey eggs are laid in straight double rows on the plant. The larva feeds mainly during the night, sheltering in cracks and under leaves by day. The larva reaches a length of 2½ inches; colour pinkish-brown with tufts of dark hairs arising from blue spots along the sides and back and an intervening row of tufts of pale pink hairs and projecting tufts of longer black hairs on each side of the head. (See D. G. Sevastopulo, 1939, *Journ. Bomb. Nat. Hist. Soc.*, XLI, pp. 315). The cocoon is tough and papery, interwoven with larval hairs and is usually tent-shaped or with protuberant ends fastened along a twig; the larval skin is pushed out from one end of the cocoon. The male moth (2 inches) is pale green with faint dark markings and a large reddish-brown patch and a dark spot on the forewing.

There are 4 or more generations a year. In the north the first moths from cold season larvae and pupae may appear at any time in January–April. The pupal period in November to January is about 50 days falling to about 35 days in February–March and to 15 days in April. There may thus be 1 or 2 complete life-cycles in the hot weather. The egg-stage lasts 11 days in April. In July the pupal period is 17 days. The rains generation lasts 7 to 8 weeks (August to October) with the egg 10 days, larva 25 days and pupa 16 days. The pupal period of later broods is in October and November about 22 days. The coldest season may be passed as caterpillar or pupa. There are 6 larval stages.

Economic importance: The species is polyphagous and occurs throughout India and Burma but principally in the sub-Himalayan region. As sporadic pest of castor it is known as the Castor Hairy Caterpillar. Damage to *Shorea robusta* forests is most frequent in Assam and Bengal and in the Central Provinces. Its other food-plants are *Anogeissus*, *Bischofia javanica*, *Berberis asiatica*, *Butea frondosa*, *Careya arborea*, *Eucalyptus robusta*, *Eugenia jambolana*, *Lagerstroemia flosreginae*, *Lantana*, *Mallotus philippinensis*, *Psidium guava*, *Quercus dilatata*, *Q. incana*, *Quisqualis indica*, *Shorea robusta*, *Terminalia belerica*, *T. myriocarpa*, *T. tomentosa*, *Verbascum thapsus*.

LIMACODIDAE

CATERPILLARS of this family exhibit a variety of forms which have given rise to the common names "slug caterpillars," "nettle grubs," "gelatine grubs." They are broad, fat-bodied with the

head and legs concealed from above and move with a gliding or slug-like motion. The body in some cases is quite smooth, in others protected with tubercles and irritant spines. The cocoon is oval or spherical with a hard, often shell-like exterior; it opens by means of a lid or cap at one end.

Hampson G. F., 1892, *Fauna Brit. Ind.*, Moths I, pp. 371-402, figs. 252-277, Limacodidae.

Altha nivea feeds on *Bombax malabaricum* and *Terminalia myriocarpa*.

Belippa laleana. This gelatine grub feeds on *Aleurites fordii*, *Butea frondosa*, *Derris elliptica*, *Schleichera trijuga* and fruit trees, apple, pear, walnut and on coffee, cocoa and tea; it is probably a general feeder.

Contheyla rotunda is occasionally a pest of *Cocos nucifera*, killing the foliage and sometimes the flowering shoots and rinds of young nuts.

Hyphorma minax defoliates *Aleurites fordii*.

Miresa albipuncta feeds on species of *Terminalia* and *Butea frondosa*. **M. thermistis** on *Bucklandia populnea*.

Narosa conspersa, The Small Gelatine Grub. This species feeds on *Cocos nucifera*, *Feronia elephantum*, tea and coffee. The larval period of 5 instars lasts 35–40 days, the cocoon-period 20 days and the total life-cycle 8½ to 9 weeks with 6 generations a year under favourable conditions.

Hutson J. C., 1932, *Trop. Agric.*, LXXVIII, pp. 206-210, pl. iv, figs. 1-8, Nettle Grubs.

Natada nararia, The Fringed Nettle Grub. Food-plants are various trees and shrubs including *Cedrela toona*, *Erythrina indica*, *Lagerstroemia indica*, *Pithecolobium dulce*, *Sideroxylon* sp., *Trema orientalis* and tea (of which it is frequently a bad pest).

The egg is flattened scale-like, laid singly on the leaves. The colour of the larva varies and the pattern changes from instar to instar. The 5th instar or full-grown larva is 9 mm. long. It is apple-green or bright green marked with brownish or pinkish tubercles and with yellow and crimson or whitish-green stripes, and is armed with 4 rows of fleshy processes bearing spines. The cocoon is broadly oval to spherical, 6 mm. long, formed on the leaves, bark or ground, smooth when built on the soil but covered with loosely woven hairs when formed on leaves or twigs. The moth has the forewing pale brown to reddish-brown with a central darkish spot and a distal transverse pale band; hindwing pale ochreous; expanse about 19 mm. The young nettle grubs feed at numerous small spots scattered over the leaf, eating the surface-tissue and leaving pale or brown scars. Later stages make large irregular blotches and the mature larvae eat right through the leaf making ragged edges and holes. Pupation usually takes place among fallen leaves or on the top layer of soil at the foot of

the food-plant. The complete life-cycle lasts for 8 to 11 weeks (8 or 9 weeks under favourable climatic conditions in Ceylon) and may pass through 6 generations a year.

Ballard E. and Rao Y. R., 1921, *Proc. Fourth Ent. Meet. Pusa*, pp. 153-156, pl. 1, Notes on Natada nararia.

Hutson J. C., 1923, *Yearbook Dept. Agric. Ceylon*, pp. 11-15, pl. 1, The Fringed Nettle Grub.

— 1932, *Trop. Agric.*, LXXVIII, pp. 190-198, pl. ii, Nettle Grubs.

Sevastopulo B.G., 1939, *Journ. Bomb. Nat. Hist. Soc.*, XL, p. 685.

Natada velutina feeds on *Bombax malabaricum*, *Lannea grandis*, *Mangifera indica*, *Sapium insigne* and *Terminalia* spp. The larva attracts attention by the unusual development of fleshy branched poisonous spines on the body. [fig. 156, No. 9]. The moth is shown in fig. 157, No. 12.

Parasa lepida, The Blue-striped (or Green-striped) Nettle Grub. This is one of the larger species of nettle grubs and like the other species is polyphagous. The food-plants are *Aleurites montana*, *Artocarpus hirsuta*, *Barringtonia racemosa*, *Borassus flabellifer*, *Butea frondosa*, *Careya arborea*, *Cocos nucifera*, *Erythrina lithosperma*, *Eugenia* spp., *Ficus bengalensis*, *F. benjamini*, *F. carica*, *F. glomerata*, *Flacourtia ramontchi*, *Mangifera indica*, *Nephelium longana*, *Nipa fruticans*, *Randia dumetorum*, *Ricinus communis*, *Sapindus trifoliatus*, *Sapium insigne*, *Terminalia catappa*, *Vitex altissima*, tea and coffee.

Life-history: The flattened scale-like eggs are laid in clusters of 10 to 30 overlapping each other on a leaf. The caterpillar [fig. 156, No. 2] when full grown is 1 to 1⅜ths of an inch long and is bright apple-green to yellowish-green with a dorsal stripe of olive edged with dark green, or of lilac to purplish-blue edged with dark blue, and lateral stripes of pale olive edged with darker green, or of pale to bright blue edged with darker blue. The tubercles in the subdorsal row bear pale green dark-tipped spines, the two anterior pairs and the last pair but one larger and bearing 2 to 12 reddish-brown cylindrical processes in a central tuft. The sub-lateral tubercles have some of the lower spines ending in pale slender hairs. The size and appearance of the spines on the tubercles change considerably with the different instars of which there are 8 to 10. The cocoon is hemispherical or broadly flattened oval, dark brown, surrounded with loosely woven silk webbing incorporating the irritating spines from the body of the caterpillar and is usually attached to a branch or bark. The moth [fig. 157, No. 33] has the forewing with a reddish-brown basal area, an outer reddish-brown area and a broad pea-green or emerald-green area crossing the middle of the wing; the thorax is green and the abdomen brown. Expanse 28 to 40 mm. (or 1 to 1½ inches). A female probably lays 500 eggs; these hatch after 6 to 8 days. The young grubs feeds gregariously at first but take small quantities of food and grow very slowly. The larval period lasts on an average about 8 weeks. During the

first 6 instars, i.e., about a month of life, the result of feeding is a surface-spotting of the leaves. During the remaining instars holes are eaten in the leaves.

The cocoon stage lasts 40 to 50 days, but the prepupal period may be prolonged under unfavourable conditions and is the stage in which hibernation or aestivation is passed. The total life-cycle requires 15 to 17 weeks on an average for males and females respectively. Under the most suitable conditions there are 3 generations a year.

Hutson J.C., 1932, *Trop. Agric.*, LXXVIII, pp. 198-205, pl. iii, figs. 1-8, Nettle Grubs.

Sevastopulo D. G., 1939, *Journ. Bomb. Nat. Hist. Soc.*, XL, p. 684, The early stages of Indian Lepidoptera.

Thosea cana feeds on *Albizzia*, *Cassia auriculata* and tea. **T. cervina**, The Saddle-backed Nettle Grub, is a pest of tea bushes. Hutson, 1932, *tit. cit.*, p. 255, pl. v. **T. rara** feeds on *Cassia fistula* in Burma. **T. recta** is another nettle grub that defoliates tea bushes; it also feeds on *Albizzia*. **T. sinensis** defoliates *Aleurites montana*. **T. tripartita** feeds on *Shorea robusta*; the pupal period is 21 days in August, September. **T. unifasciata** feeds on *Cocos nucifera*.

Other species of **Thosea** feed on trees of the genera *Alseodaphne*, *Artocarpus*, *Buchanania*, *Careya*, *Cassia*, *Clerodendron*, *Eugenia*, *Sapindus*, *Terminalia*, etc.,

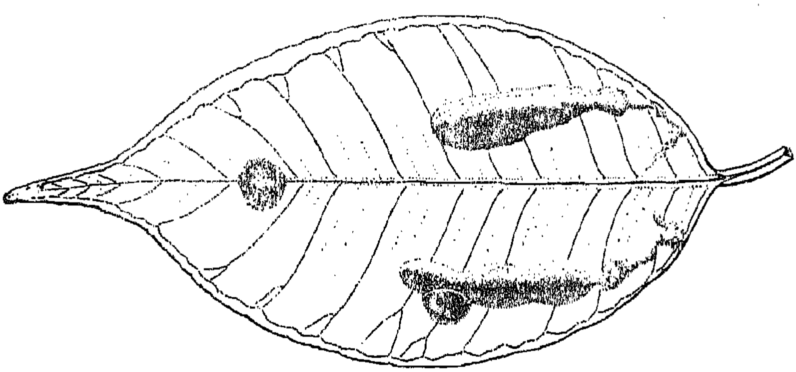
LITHOCOLLETIDAE

MOST of the species of this large microlepidopterous family make mines, blotches or blisters in leaves putting them out of action or inducing shedding of foliage out of season.

Fletcher T. B., 1921, *Mem. Dept. Agr. Ind.*, VI, pp. 137-167-209, pls. xxxiii-xlv; lxv (Gracillariadae).

— 1933, *Imp. Counc. Agr. Res., Sci. Mon.*, No. 4, pp. 38-64, pls. xxxiii-lxiv. (Lithocolletidae).

The genus **Acrocercops** contains a large number of species that are miners of the leaves of forest trees, e.g., **anthracuris** on *Pongamia glabra*; **auricilla** on *Swietenia mahagoni*; **astiopa** on *Polyalthia longifolia*; **barringtoniella** on *Barringtonia acutangula* and *Careya arborea*; **calycophthalma** on *Terminalia belerica*; **diacentrota** on *Michelia champaca*; **elaphopa** on *Ficus asperrima*; **euthycolona** on *Bassia latifolia*; **gemoniella** on *Bassia latifolia* and *Lannea grandis*; **geometra** on *Cordia myxa*; **loxias** and **phaeospora** [fig. 173] on *Eugenia jambolana* and *E. operculata*; **lysibathra** on *Cordia latifolia*; **ordinatella** on *Alseodaphne semecarpifolia*, *Phoebe lanceolata* and *Litsaea polyantha*; **scandalota** on *Helicteres isora* and *Mallotus philippinensis*; **scriptulata** and **vanula** on *Terminalia paniculata*; **syrista** on *Mallotus philippinensis*; **tenera** on *Schleichera trijuga*; **telestis** on *Eugenia jambolana*, *Gmelina arborea* and *Trewia*



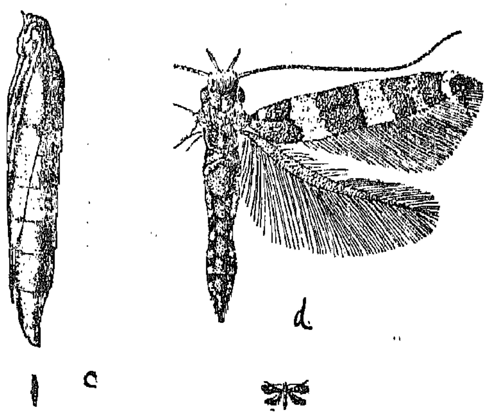


Fig. 173. Acrocercops phaeospora; blisters on leaf of Eugenia.

nudiflora; **terminaliae** and 4 other species on *Terminalia catappa*; **tetradeta** on *Ixora coccinea*; **thrylodes** on *Carissa carandas*; **ustulatella** on *Diospyros embryopteris*; **vanula** on *Terminalia tomentosa*. The moths, early stages and mines of many of these species are figured by Fletcher *tit. cit.*

Caloptilia acidula mines the leaves of *Phyllanthus emblica* and when full fed escapes from the mine through a round hole bitten in the upper epidermis and twists another green leaflet into a cone to form a pupal chamber. Fletcher, 1921, pl. xliii (coloured).

Caloptilia tetratypa rolls the leaves of *Sapium sebiferum* and feeds on the surface in patches; the leaves shrivel and are often webbed together with silk. Larva about 6 mm. long dropping by a silken thread when disturbed. Moth dark with 8 white dots. Several generations occur in the monsoon and autumn with short life-cycles. Fletcher, 1933, *tit. cit.*, pp. 59, 63, pl. lxiii.

Caloptilia zonotarsa curls the leaf of *Phoebe lanceolata*.

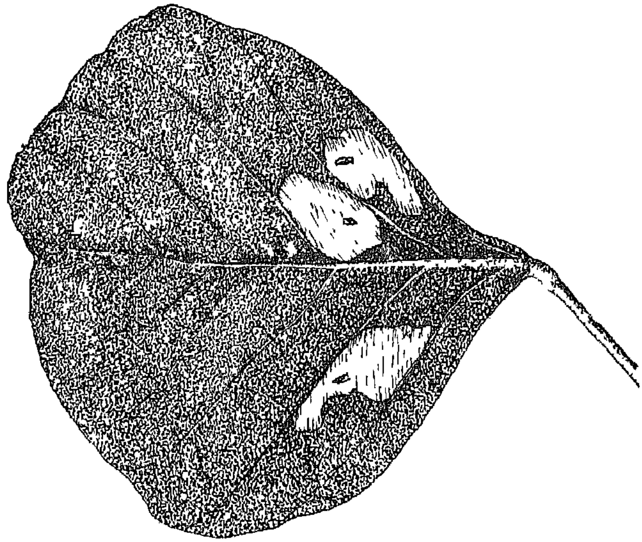


Fig. 174. Blotches in the leaf of Butea frondosa due to Lithocolletis virgulata.

Epicephala chalybacma feeds inside the unopened flowers of *Caesalpinia pulcherrima* and *Pithecolobium saman*; when full fed the larva gnaws its way out of the flowers and drops to a leaflet on the surface of which it pupates in a cocoon ornamented with minute bubbles. Fletcher, 1921, *tit. cit.*, pl. xxxvi (coloured). **E. orientalis** mines the leaves of *Bauhinia purpurea* and *B. variegata*. Fletcher, 1933, *tit. cit.*, pl. xlii.

Lithocolletis dorinda mines the leaves of *Desmodium* sp. and *Uraria neglecta*. **L. bauhiniae** mines leaves of *Bauhinia acuminata* and *B. purpurea*. Fletcher, 1933, *tit. cit.*, pl. xxxiii. **L. eophanes** and **iteina** make irregular blotches on the underside of leaves of *Salix tetrasperma*. Fletcher, 1933, *tit. cit.*, pl. xxxv. **L. virgulata** mines blotches or blisters in the leaves of *Butea frondosa* [fig. 174] and *Pongamia glabra*. Fletcher, 1921, *tit. cit.*, pl. xxxiv.

Metharmostis asaphaula bores the needles of *Casuarina equisetifolia*, sometimes completely destroying nurseries of young plants in September, October.

Phyllocnistis amydropa mines the leaf of *Gmelina arborea*.

Phyllocnistis citrella, The Citrus Leaf Miner, is a common pest of *Citrus* in the Far East. It also attacks *Aegle marmelos*, *Alseodaphne semecarpifolia*, *Jasminum sambac* and *Murraya koenigi*. The egg is laid singly on the upper or under side of the young leaf near the midrib. The greenish-yellow larva bores into the leaf and eats out a serpentine mine feeding on the sap of

the epidermis and adjacent layers of cells, leaf-tissue is not eaten. The dead epidermis forms a transparent shining blotch and the leaf curls or wrinkles. The growth of young leaves completely stops. When the attack is heavy almost all the new foliage is injured and the growth of the shoots is entirely checked, but the tree is rarely killed. Pupation takes place near the edge of the leaf in a chamber partly lined with fine silk. The life-cycle is about six weeks with hibernation as a moth. In south India and Ceylon the life-cycle is completed in 2 weeks.

Fletcher, 1921, *tit. cit*, pp. 171-172, 214, pl. xlvii, xlix (Lyonetiadae).
Hutson J. C, 1934, *Trop Agric.*, LXXXIII, pp 188-191, pl coloured, 6 figs, The Citrus leaf miner.

P. citronympha mines the under-surface of the leaves of *Lannea grandis*. **P. synglypta** mines an irregular tunnel on either side of leaves of *Terminalia tomentosa*, also of *Capparis* sp. The excrement is liquid and forms a black line down the centre of the gallery.

LYCAENIDAE

Bell T. R. D., 1914-1920, *Journ. Bomb. Nat. Hist Soc*, XXIII, pp. 482-497, pl G, XXIV, pp 656-672, XXV, pp 430-453, 636-664, XXVI, pp 98-140, 438-487, 750-769, 941-954, XXVII, pp 26-32, The common butterflies of the plains of India
Bingham C. T, 1907, *Fauna Brit. Ind*, Butterflies II, pp. 282-472, pls. 19, 20 (Lycaenidae)
Evans W H, 1927, *Guide to the Identification of Indian Butterflies*, pp 130-195, pls, 26-29.

Amblypodia amantes occasionally feeds on *Shorea robusta*.

A. asopia feeds on the foliage of *Dipterocarpus pilosus*.

Arhopala atrax has been recorded as a defoliator of *Shorea robusta*. **A. centaurus** feeds on *Terminalia* and *Lagerstroemia*.

Other species of *Arhopala* feed on *Quercus incana*.

Curetis bulis on *Ougenia dalbergioides*.

C. thetis on *Pongamia glabra*.

Euchrysops pandava feeds on *Bauhinia retusa*, *B. variegata*, *B. vahlii*, *Xylia dolabriformis*.

Lampides boeticus on *Butea frondosa* and *Xylia dolabriformis*. This widespread species is a most regular migrant in the Indian region; in the Himalayan foothills it flights to the N. and NW. in February–April and in south India to the S. or SE. in January–March. Williams C. B., 1938, *Journ. Bomb. Nat. Hist. Soc.*, XL, pp. 436–457.

Lampides elpis. The caterpillar feeds on the flowers and bores into the fruits of *Elettaria cardamomi*.

Rapala jerbas feeds on *Xylia dolabriformis*. **R. melampus** occasionally defoliates *Ougeinia dalbergioides*.

Surendra quercetorum feeds on *Albizzia odoratissima*.

Tarucus venosus feeds on *Zizyphus jujuba*.

Thaduka multicaudata kanara feeds inside the folded edges of

young leaves of *Trewia nudiflora*, lining the shelter with silk and eating holes all round through both layers except at the hinge. Pupation occurs in crevices in the bark or in the soil-covering. Bell T. R. D., *Journ. Bomb. Nat. Hist. Soc.*, XXVI, p. 750.

Virachola isocrates. The larvae feed on the seeds and pulp inside the fruits of pomegranates, *Punica granatum*; before pupating the larva emerges and binds the fruit to the stalk so that it cannot fall down. It is a pest in the forests of Kashmir and the Punjab. The Agricultural Research Institute, Pusa, has issued a coloured plate. See Caius J. F., 1940, *Journ. Bomb. Nat. Hist. Soc.*, XLII, pp. 21–26, The pomegranate, and Part Two for control measures.

Virachola perse. The larva feeds and pupates in fruits of *Randia dumetorum*.

LYMANTRIIDAE

MANY species of this family feed on forest trees and several are notorious pests in forests of temperate regions, e.g., the Nun Moth, the Gypsy Moth. Species of *Dasychira*, *Euproctis* and *Lymantria* appear in epidemics at intervals in forests of India and Burma and cause widespread defoliation. The caterpillars have an extremely hairy appearance [figs. 175, 176] due to the presence of setae borne on warts and long or very long hairs in brushes and tufts. The colour-pattern and arrangement of hairs often vary in successive instars.

Gardner J. C. M., 1938, *Ind. For. Rec.*, Ent., III, 10, Immature stages of Indian Lepidoptera (1) Lymantriidae (descriptions of larvae).
Chatterjee N. C. 1935, *Ind. For Rec.*, Ent., I, 10 (Lymantriidae of sandal).
— 1940, *tit. cit* VI, No. 3, pp. 63-65, (Lymantriidae of lantana).
Hampson G. F, 1892. *Fauna Brit. Ind*, Moths, I, pp. 432-494, figs. 300-328, Lymantriidae.

Casama vilis defoliates *Acacia catechu* and *Prosopis spicigera*.

Caviria ochripes defoliates *Litsaea chinensis*, *L. polyantha*, *L. sebifera*, *Mallotus philippinensis*, *Phoebe lanceolata*, and *Sapium sebiferum*. The defoliation of *Litsaea polyantha* is serious in years of deficient rainfall. Larvae occurring during the monsoon season pupate in September, October, the moths emerging in October, November. The larvae of the next generation are active throughout the cold months in north-west India but these winter broods are of slow development with 9 moults and the moths emerge in March after a pupal period of about three weeks or in April, May after a pupal period of about 8 days. Another generation matures in June, July with a pupal period of 8 days. The eggs are laid without hair covering in single rows on the leaf. The larval stages are described by Gardner, 1938, *Ind. For. Rec.*, Ent., III, 10, p. 202, figs. 9, 20, 21; the fullgrown larva is about 40 mm. long. [fig. 156, No. 12]. Pupation occurs on a leaf without the formation of a definite cocoon.

Dasychira araea feeds on *Morus indica* in Burma.

Dasychira cerigoides. The moth of this species somewhat resembles the male of *Dasychira grotei* in markings. It is a defoliator of *Dipterocarpus tuberculatus* and *Pentacme suavis* in Burma. Successive broods of caterpillars occur in May, July, August–November, completely defoliating *in* and *eng* forests but not attacking teak and other associates. Unburnt areas suffer more than burnt areas. The life-cycle lasts about 75 days. A severe outbreak occurred in 1938, 1939 in north Burma.

Dasychira dalbergiae, a defoliator of *Bauhinia variegata, Cassia tora, Dalbergia latifolia, D. sissoo, Eugenia jambolana, Geranium* sp., *Lantana aculeata, Mangifera indica, Prunus communis, Ricinus communis, Shorea robusta, Terminalia myriocarpa.*

In north-west India caterpillars occur through the cold season, October–March, and pupate at various times from December to March giving moths in February–April after a pupal period of 2 to 5 weeks. Another generation occurs during the hot weather with a pupal period of 7–9 days and moths in April, May, and again during the monsoon with moths in September–November. The larva is described by Gardner, 1938, *tit. cit.*, p. 197. There are 5 larval stages and the full-grown caterpillar is about 40 mm. long. Pupation occurs in a cocoon of silk mixed with larval hairs.

Dasychira dehra feeds on *Catalpa* sp., *Quercus serrata, Shorea robusta* and *Terminalia crenulata.* This species is probably a cold season variation of *Dasychira grotei* in north-west India. Larvae occurring through the cold season, September–January, pupate in December, January and produce moths in February, March after a pupal period of 56 to 38 days. From eggs laid in February the larvae pupate in April and produce moths in April, May (egg-period 22–24 days, larval period 39–48 days with 6 moults, pupal period 7–13 days). The moths of this first generation of the year are of the *grotei* form. Gardner J.C.M., 1940, *Ind. Journ. Ent.*, II, p. 93.

Dasychira fusiformis feeds on *Terminalia tomentosa.*

Dasychira grotei. The food-plants of this species are *Acacia arabica, Berberis* sp., *Eugenia aquea, Lagerstroemia flos-reginae, Mallotus philippinensis, Psidium guava, Quercus incana, Shorea robusta, Tectona grandis, Terminalia crenulata, Wagatea spicata.* This species (previously referred to in departmental literature as *Dasychira horsfieldi*) occurs in India in the plains as well as at 7,000 feet elevation in the Himalayas.

Life-history: The larva [fig. 156, No. 7] is pale green or yellowish with rows of brushes of very long white hairs, 4 dorsal cones of yellow hair on the 1st 4 abdominal segments, a black velvety patch between the 1st and 2nd cones, and a long white tuft on the last segment. Length $1\frac{1}{4}$ to 2 inches. The larva is described by Gardner, 1938, *tit. cit.*, p. 197. There are

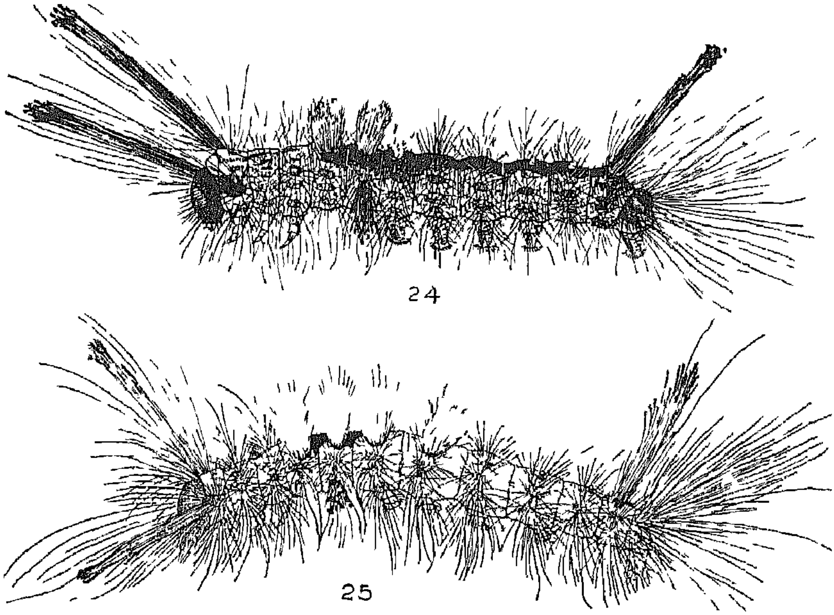


Fig. 175. Dasychira mendosa, No. 24, 4th instar larva, lateral view; No 25 full grown larva, 45 mm.

6–8 moults Larvae occurring in the cold season in north-west India, pupate in November–January and produce moths in February, March after a pupal period of 4–7 weeks, in Assam, Bengal the life cycle is shorter and moths appear in January, February. This cold season generation is probably identical with *D dehra*. Eggs laid in February produce moths [fig 157, No 18] at the end of April (western U P) or early in April (Bengal), later broods give rise to moths in June (pupal period 9 days) and in August (pupal period 9 days) Larvae occurring during the monsoon produce moths in September November (pupal period in November 30 days) There are normally 4 generations a year. Development is often quicker on *Shorea robusta* than on other food-plants

E c o n o m i c i m p o r t a n c e This species appears at intervals in epidemics extending over hundreds of square miles of sal forests particularly in Assam, it is usually accompanied by *Dasychira thwaitesi*, *Lymantria* spp. and other Lymantriids The earliest recorded epidemic occurred in Goalpara in 1878, severe outbreaks also occurred in 1884 over 200 square miles of sal forest north of the Brahmaputra and again in 1897 (Assam), 1899 (Bengal), 1907 (Assam), 1909 (C. P), 1914 and 1922 (Assam), 1936 (Assam). Defoliation is most severe from August

to October but may continue through the cold weather. Trees of all ages are attacked and the whole of the leaf except the ribs is eaten; after two or three successive defoliations the tree is killed. In epidemic outbreaks the associates of sal such as *Bombax*, *Dillenia*, *Schima*, *Albizzia* and *Careya* are rarely attacked.

Dasychira mendosa. Eggs are laid in a mass; the egg is yellow, 0·5 to 0·7 mm. The larva [fig. 156, No. 11] is yellowish to greyish, spotted with red and with red stripes on the prothorax and paired lateral tufts of greyish-white hairs on each segment of the body and the head. The metanotum has an additional pair of long white tufts; about 1½ inches long. It is described by Gardner, 1938, *tit. cit.*, figs. 5, 25–28 [fig. 175] also by D.G. Sevastopulo, 1938, *Journ. Bomb. Nat. Hist. Soc.*, XL, p. 404. There are 4 or 5 moults. Pupation occurs in a loose cocoon of silk and hairs. The moth has the forewing patterned in various shades of brown and the hind wing pale. There are possibly 5 or 6 generations annually with a life-cycle of 26-55 days. In June–August the pupal period is 7 to 10 days. In September the egg-stage is 5 days, the larval period 15-25 days, the pupal period 7–11 days.

The species is widely distributed in India, Burma and Ceylon and is polyphagous. The food plants include *Acacia catechu*, *Aleurites fordii* and *montana*, *Careya arborea*, *Dalbergia sissoo*, *Dipterocarpus tuberculatus*, *Ficus* spp., *Lagersroemia indica*, *Lantana aculeata*, *Grewia microcos*, *Mangifera indica*, *Schleichera trijuga*, *Shorea robusta*, *Tectona grandis*, *Terminalia belerica*, *T. paniculata*, *T. tomentosa*, castor, maize and coffee and other cultivated plants.

D. pennatula feeds on *Tectona grandis*. **D. strigata** defoliates *Quercus incana*.

Euproctis albodentata feeds on *Michelia champaca*. **E. bipartita** on *Shorea robusta* new flush in Bengal and the United Provinces. The larva is described by Gardner, *tit. cit.*, p. 205, fig. 6. **E. bipunctapex** is an occasional feeder on *Aleurites cordata*, *Careya arborea*, *Eugenia jambolana*, *Glochidion velutinum*, *Ricinus communis*, *Sapium sebiferum*, *Shorea robusta*, *Terminalia myriocarpa*, *T. paniculata*, *T. tomentosa*. It occurs from Kashmir to China. The pupal period is 9–13 days in April. The larva is described by Gardner, 1938, *tit. cit.*, p. 204, figs. 7, 40.

E. fraterna feeds on *Aleurites fordii*, *A. montana*, *Mangifera indica*, *Ougeinia dalbergioides*, *Quisqualis indica*, *Shorea robusta*, *Tectona grandis*, *Terminalia tomentosa*, *Trewia nudiflora*, *Zizyphus jujuba*. The pupal period is 15–19 days in June, July. The larva is described by Gardner, 1938, *tit. cit.*, p. 207, figs. 8, 43.

Euproctis guttata defoliates *Anogeissus acuminata*, *Barringtonia acutangula*, *Jasminum*, *Lagerstroemia indica*, *Lantana aculeata*, *Maesa indica*, *Mallotus phillippensis*, *Mangifera indica*,

Ricinus communis, *Shorea robusta*, *Terminalia myriocarpa*, *T. tomentosa*. The pupal period is 11–14 days in April–June, 8–14 days in August and September. The larva is described by Gardner, 1938, *tit. cit.*, p. 207 and Sevastopulo, 1939, *Journ. Bomb. Nat. Hist. Soc.*, XLI, p. 313. **E. latifascia** defoliates young plants of *Shorea robusta* in the rains attacking the new shoots and eventually killing the plants. It occurs from Kashmir to Indo China. **E. limbata** feeds on *Cassia nodosa* in Burma. **E. lunata** defoliates *Cinnamomum camphora*, *Mangifera indica*, *Morus* sp., *Terminalia tomentosa* and *Zizyphus jujuba*. It occurs from Kashmir to Ceylon. The larva is described by Gardner, 1938, *tit. cit.*, p. 206, fig. 42. **E. phaulida** feeds on *Terminalia tomentosa* in April, May.

Euproctis scintillans defoliates *Acacia arabica*, *Aesculus indica*, *Buchanania latifolia*, *Cassia fistula*, *Ficus bengalensis*, *F. glomerata*, *Lagerstroemia indica*, *Lantana aculeata*, *Shorea robusta*, bamboo and many agricultural crops. The larva is described by Gardner, 1938, *tit. cit.*, p. 206, and by Sevastopulo, 1938, *Journ. Bomb. Nat. Hist. Soc.*, XL p. 406. In April the pupal period is 9–12 days; in August 8 days. Larvae occurring from October onwards through the cold season in north India may pupate at any time between November and March with a pupal period of 16–30 days. **E signata**, a snow-white moth with a golden yellow anal brush, is a polyphagous species in Kashmir and the north-west Himalayas responsible for wholesale defoliation, usually in June, of *Aesculus indica*, *Acer* spp., *Juglans regia*, *Parrotia jacquemontiana*, *Pyrus* spp., *Salix* spp. The hairy caterpillar is credited with poisonous properties. **E. subfasciata** on *Quisqualis indica*; Sevastopulo, 1940, *Journ. Bomb. Nat. Hist. Soc.*, XLII p. 41 (larva).

E. sulphurescens feeds on *Lantana aculeata* occasionally, eating the flowers and young leaves in the early larval stages and the foliage only in the late larval stages. The larva is described by Gardner, 1938, *tit cit.*, p. 206, fig. 41; there are 6 moults; the full-grown larva is 32 mm. During the monsoon-season the life-cycle lasts 52–57 days (egg-stage 5 or 6 days, larva 32 days, pupa 15–19 days). Eggs laid in September hatch in 6 days and the larvae feed until December when they pupate and hibernate as pupae until the spring.

Laelia exclamationis feeds on dub and other grasses and pupates in the soil. **L. devestita** feeds on the grass, *Imperata arundinacea*. The pupal period lasts one week in August. **L. litura** and **L umbrina** also feed on grass and small weeds. The larvae are described by Gardner, 1938, *tit. cit.*, p. 199, figs. 30, 31.

Lymantria ampla occurs in India, Burma Ceylon. Eggs are laid on the food-plants in masses covered with hairs from the female's body. The full-grown larva is 1½ to 2 inches long; colour

coffee-brown, a black velvety band between pro- and mesothorax, on each segment a transverse row of papules bearing tufts of long hairs, the tufts on each side of the prothorax and a group of tufts on the last abdominal segment being more conspicuous. The pupa is chocolate-brown, ½ an inch long, with tufts of short hairs on the abdomen and thorax. No cocoon is formed. The male moth is brown with lighter and darker brown markings on the forewings; expanse over an inch. The brown large-bodied female has rudimentary scale-like white wings and does not fly. For the purpose of pairing the male discovers the female by scent. There are probably four broods a year with moths in January, April, June and October; the life-cycle is from 7 to 10 weeks. It feeds on *Carissa carandas*, *Ficus religiosa*, *Tectona grandis*, *Terminalia paniculata*, *Trewia nudiflora* and a variety of cultivated plants, garden and agricultural crops.

Lymantria bivittata feeds on *Shorea robusta*, and *Terminalia myriocarpa* in Assam and Bengal. Larvae occurring in the cold season produce moths in February after a pupal period of 3 to 5 weeks. **L. concolor** defoliates *Quercus incana* and *Q. serrata* in the western Himalayas during the rainy and postmonsoon seasons. Eggs laid in October hibernate at high elevations but hatch at lower levels (2,000 ft.) after 16 days and the larvae feed for 60–75 days, pupating in December, January and yielding moths in January, February after a pupal period of one month. The moth [fig. 157, No. 20] has the wings white with black angular markings on the forewings; expanse 2 to 3 inches. The full-grown larva is about 45 mm. long and is described by Gardner, 1938, *tit. cit.*, p. 193. **L. incerta** feeds on *Terminalia myriocarpa*. Larvae occuring in January pupate in February with moths in March after a pupal period of 15 or 16 days. **L. lepcha** is one of the species defoliating *Shorea robusta* in Assam.

Lymantria mathura. The larva reaches a length of 2 inches in the male and 3½ inches in the female, colour ashy with yellow bands across the thorax; abdomen with rows of papules bearing tufts of long hairs; two long plumes of hair project on either side of the head. It is technically described by Gardner, 1938, *tit. cit.*, p. 192, figs. 4, 38. Pupation takes place in a leaf fastened with a few strands of silk. The pupa is ½ to 1 inch long, smooth except for a few groups of short bristles. The female moth has a white forewing with dark markings and edged with pink; hindwing pink with a band of dark brown; abdomen half white half pink, legs pink and black; expanse 3 to 4 inches. The male with the forewing mainly marked with dark brown; hindwing yellow with a black spot and line. A brood of larvae is found in April with moths in May after a pupal period of 8 to 10 days; larvae occur again during the hot weather and early rains, pupation occurs from July to September with moths after about ten days. Eggs of another generation are laid in October.

Fig. 176. Larva of Lymantria nigra.

Economic importance: The species is one of the principal defoliators of *Shorea robusta* in Assam and north India. Other food-plants are *Eugenia jambolana*, *Quercus incana*, *Quercus serrata*, *Terminalia arjuna*, *T. myriocarpa*.

Lymantria nigra feeds on *Mangifera indica* and *Ficus religiosa*; the full-grown larva is about 45 mm. and is described by Gardner, 1938, *tit. cit.*, p. 194, figs. 32, 33. (Previously referred to in economic literature as *Lymantria beatrix*.)

Lymantria obfuscata. The eggs hatch in early April and the caterpillar feeds for about six weeks. Feeding takes place during the cooler hours of the day and at night and during the middle of the day the caterpillars (of all stages) congregate in colonies of dozens or hundreds of individuals on the bark of the trunk, on the underside of branches, in forks, under the shelter of epicormic shoots and the foliage of ground-plants, under stones, etc. The full-grown larva is about 45 mm. long and is described by Gardner, 1938, *tit. cit.*, p. 193, figs. 34, 35. When full-grown in June they collect in similar places for pupation which occurs with the assistance of irregular webs of sticky silk. The pupal period lasts 10 to 14 days and emergence of moths occurs during June and July. The female is of the apterous type, i.e., has the wings feebly developed and the body relatively bulky and is unable to fly. After being found and fertilised by the winged male, the female lays on the bark or under the shelter of rocks or in overhung cavities in masses covered with a felted layer of yellow hairs and scales rubbed off the body of the female. The site of the egg-masses is always close to the site of pupation and often among the empty pupal skins. The eggs remain unhatched until next spring. The female dies as soon as the ovaries are empty.

Economic importance: The species is a defoliator of alder, *Alnus nitida*, oaks, *Quercus dilatata*, willows, *Salix alba*, and *Salix fragilis*, in Kashmir and the north-west Himalayas as far as Kangra and has appeared as a pest in willow plantations in Kashmir. It possibly feeds on cultivated fruit trees also.

Lymantria semicincta. The full-grown larva is about 50 mm. long, greyish-brown with tufts of brownish hairs along the sides of the body. It is described by Gardner, 1938, *tit. cit.*, p. 192, figs. 1-3, 36, 37. The female moth has the prothorax yellow and

the forewing black with yellowish or orange spots and the hindwing crimson bordered with black. The male moth has no yellow markings. Defoliation occurs in April–June with pupation in May–July (pupal period 8 days). Another generation occurs in July pupating in the soil-cover in September with a pupal period of 7 days. During the hot weather and monsoon the larvae feed only at night sheltering in the soil-cover during daytime. The species occurs in the outer Himalayas but seems to be of importance only in the Central Provinces and Assam. The only food-plant known is *Shorea robusta*. **L. serva** feeds on *Shorea robusta* in Assam. **L. subrosea** defoliates *Shorea robusta* in Assam, appearing in abundance in August and continuing throughout the cold weather. The incubation-period of the egg in October is 6 days, the larval period 3 months in the cold season, and the pupal period 2 weeks in February. An epidemic occurred in Goalpara in 1933–35. It occurs also in Ceylon. **L. todara** is one of the species defoliating *Shorea robusta* in Assam. **L. viola** feeds on *Terminalia tomentosa*.

Orgyia postica is a general feeder occurring on *Albizzia* spp., *Anogeissus latifolia*, *Callicarpa lanata*, *Erythrina lithosperma*, *Lagerstroemia flos-reginae*, *L. indica*, *Pithecolobium dulce*, *Ricinus communis*, *Shorea robusta*, *Tectona grandis*, *Zizyphus jujuba*, *Z. xylopyra* throughout India and Burma. It occasionally defoliates forests containing *Anogeissus latifolia* over large areas.

Life-history: The male moth has brownish wings mottled with black but the female has only rudiments of wings and is generally inactive. The eggs are laid in masses of up to 600 on or near the female cocoon. They hatch in 7 to 11 days and the young larvae feed gregariously chiefly on young foliage. The older larvae, 1½ ins, have reddish heads and four closely set short tufts of yellowish to brownish hairs on the back, and a pencil of feathery hairs projecting forwards on each side of the head, and a pair of long brownish tufts extending backwards from the last segment. A technical description of the larva is given by Gardner, 1938, *tit. cit.*, p. 198; see also Sevastopulo, 1938, *tit. cit.*, p. 405. The larval period is 16 to 20 days in warmer seasons and up to 50 days in cold localities. The cocoons are spun between two or three leaves or on twigs and are covered with hairs or larval excrement. The pupal period is 7 to 9 days. The insect is abundant in June and July and again in October and has 5 to 7 generations a year.

Ayyar T. V. R., 1919, *Proc. Third Ent. Meet.*, I, pl. 17, figs. 10 (coloured).
Hutson J. C., 1932, *Trop. Agric.*, LXXVIII, No. 3, p. 133, pl. iii, figs. 1-8.
— 1936, *Ceylon Dept. Agr.*, *Yearbook*, pp. 19-21.

Orgyia turbata feeds on *Mimosa pudica* and also on *Aleurites montana*, *Centrosema plumieri*, *Derris elliptica*, and *Ricinus communis* in Burma and the Malay Peninsula. Caterpillars may spread from wild food-plants into tree-nurseries. The full-grown

caterpillar is 20 mm. long, blackish with a long tuft of black hairs on each side of the head. The first four abdominal segments have dorsal tufts of hair usually yellow. The female moth is wingless. The forewings of the male are brown with dark markings and 3 or 4 large orange spots. The life-cycle may be completed in one month.

Corbett and Dover C., 1927, *Malay Agric. Journ.*, xv, p. 240.

Perina nuda feeds on *Artocarpus integrifolia*, *Ficus glomerata*, *F. religiosa*, *F. pumila*. Eggs laid in October give rise to larvae pupating in December with moths in January. The full grown larva is about 30 mm. long and is described by Gardner, 1938. *tit. cit.*, p. 201, figs. 14–16; see also Sevastopulo, 1938, *tit. cit.*, p. 405. There appear to be 8 larval instars and the pupa is not formed in a cocoon.

Porthesia virguncula feeds on *Cassia tora* and grasses; the pupal period is about 8 days in August-September.

Redoa phrika feeds on *Shorea robusta*. The full-grown larva is about 30 mm. long and is described by Gardner, 1938, p. 201, figs. 10, 11, 17–19.

Stilponita cygna feeds on *Alseodaphne owdenii*, *Cinnamomum camphora*, *Michelia champaca*, and *Phoebe lanceolata*. The pupal period in September is 8 days and in December 20-25 days. The larva when full-grown is about 35 mm. and is described by Gardner, 1938, *tit. cit.*, p. 200, figs. 12, 13, 22, 23.

LYONETIIDAE

Fletcher T. B., 1921, *Mem. Dept. Agr. Ind.*, vi, pp. 171-180, 214-216, pls. xlvii-lii, lxvi-lxviii (Lyonetiadae).

— 1933, *Imp. Counc. Agr. Res.*, *Sci. Mon.* No. 4, pp. 65-73, pls. lxvi-lxx.

Bucculatrix crateracma mines the leaves of *Bombax malabaricum*. Fletcher, 1933, *tit. cit.*, pl. lxx. **B. verax** eats small holes in the leaves of *Trewia nudiflora*.

Decadarchis minuscula breeds in seeds of *Hibiscus tiliaceus*.

Leucoptera sphenograpta. Moth, shining white, forewing narrow, tipped with ochreous and a black apical spot and fuscous bars. Egg, oblong-oval, white, reticulated, 0·31 mm. Caterpillar, light green with light brown head, constricted between segments, tapering, 5 mm. Pupa, light brown above and black below, spindle shaped, 3·5 mm. [fig. 177].

The species is a leaf-miner, destructive to young plants and young foliage of *Dalbergia sissoo*, causing premature leaf shedding. Badly infested trees are recognisable by the spotted foliage which later curls up and drops. The egg is laid on the lower surface of the young leaf near the edge and hatches in 2 to 5 days. The caterpillar mines into the leaf forming a tortuous line which expands into an irregular blotch ½–1 inch across; the

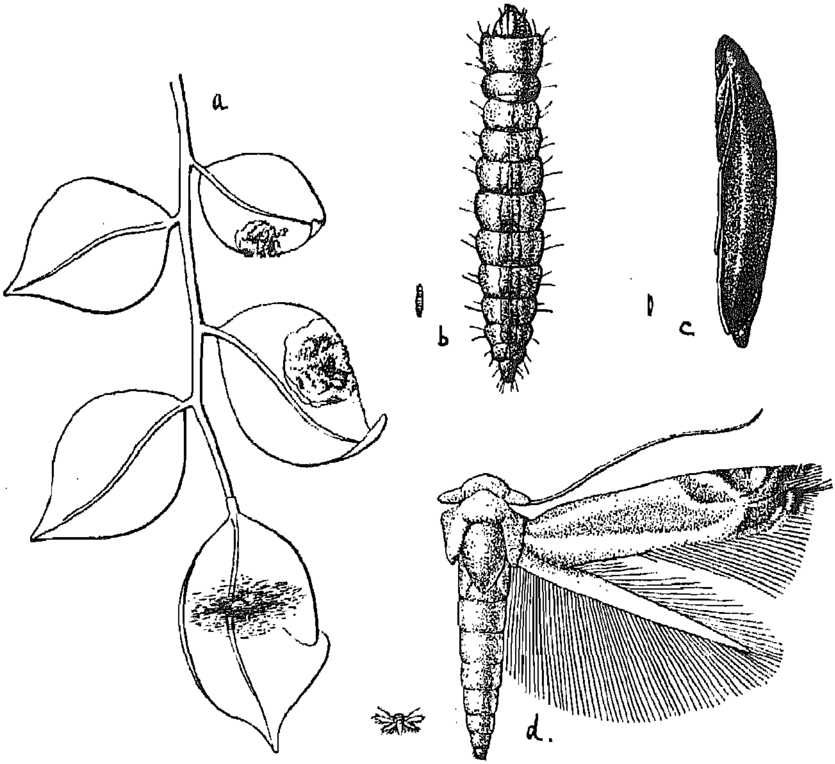


Fig. 177. Leucoptera sphenograpta, a leaf-miner of Dalbergia sissoo.

palisade-tissue and large veins are destroyed between the upper and the lower epidermis and the leaf discolours. [fig. 177 *a*]. The larval period lasts for 11 to 28 days during March to May and from 7 to 19 days during the hottest months and from 15 to 30 days during September–November. The full grown caterpillar leaves the mine and spins on the upper surface of a green leaf a white glistening web with broad x-shaped cross-cables; below this the pupation-cocoon is formed. The pupal period takes 10 days during March–April, 5 to 9 days during May to October and 11 to 22 days in November. There are 9 generations in the year in northern India. The winter is passed as an inactive moth; oviposition recommences as soon as the new foliage appears.

Beeson, 1938, *Ind. For. Rec.*, Ent., IV, No. 1, pp. 14, 15, Guide to the insects of Dalbergia sissoo.
Fletcher T. B., 1933, *tit. cit.*, pp. 67-69, pl. lxvii, figs. 1-6.
— 1921, *tit. cit.*, p. 171, pl. xlvii, fig. 2 *a-d*.

Pyloetis mimosae feeds in the seeds of *Acacia arabica*, *Cassia corymbosa* and *Cassia fistula*. (Fletcher, 1921, pl. li, fig. 2).

Species of **Opogona** feed under the bark of dead trees, e.g., **O. xanthocrita.**

Tischeria compta mines the upper cuticle of leaves of *Terminalia chebula*. **T. ptarmica** mines the upper sides of leaves of *Zizyphus jujuba.*

NOCTUIDAE

A VERY large family containing many important pests of agriculture and forestry. The species of the Indian region have not been monographed since Hampson's *Fauna* volumes appeared; as now defined the family includes the Agaristidae and excludes the Hyblaeidae. Preliminary studies of the larvae have been made by Gardner, 1941. The feeding-habits include defoliators, budworms, bollworms, fruit-borers, predators; none are true wood-borers. The length of the life-cycle varies from annual in temperate climates at high elevations to 13 generations per annum.

LITERATURE ON NOCTUIDAE:

Gardner J. C. M., 1941, *Ind. For. Rec.*, Ent., VI., No. 8, pp. 252-296, pls. i, ii, Immature stages of Indian Lepidoptera (2) Noctuidae, Hypsidae.
Hampson G. F., 1894, *Fauna Brit. Ind.*, Moths, II, pp. 148-160, figs. 98-104, Agaristidae, pp. 160-582, figs. 105-325, Noctuidae.

Achaea janata. The Castor Semi-looper, a widespread species, is a pest of castor and of several forest trees particularly in plantations, *Acacia arabica*, *Albizzia amara*, *Aleurites montana*, *Anogeissus latifolia*, *Bassia latifolia*, *Bauhinia vahlii*, *Careya arborea*. *Grewia microcos*, and also occasionally feeds on *Acacia farnesiana*, *Euphorbia pilulifera*, *Lagerstroemia parviflora*, *Phyllanthus emblica*, *Sapium sebiferum*, *Schleichera trijuga*, *Shorea robusta*, *Sterculia urens*, *Xylia dolabriformis*, *Zizyphus jujuba*. The larva is a semi-looper, bluish-grey to brown with a red lateral stripe and a pair of red projections on the last segment but one; length 2–3 inches. Diagnostic characters are given in *Ind. For. Rec.*, Ent., VI, No. 8, p. 281, fig. 1. It is most abundant during the monsoon-season when several generations are passed with a larval period of 12–21 days and pupal period of 10–15 days. Pupation takes place in the soil in a loose cocoon with hibernation in the cold weather for up to 3 months. The moth has a wing-expanse of 50–70 mm. There are 3 or 4 generations a year in north India.

Acontia intersepta defoliates *Hibiscus esculentus*, *H. tiliaceus*, *Kydia calycina*, *Urena lobata* ;widespread in the Oriental Region. Caterpillar 40 mm.; pupation in soil; moth 45–50 mm. Larval characters are given in *tit. cit.*, p. 278. **A. malvae** feeds on *Abutilon bidentatum.*

Acronycta maxima. The larva is a blue-black hairy caterpillar, 50 mm., responsible for the defoliation of *Aesculus indica*, *Cedrela serrata* and *Juglans regia* in the Himalayas and in Burma. The life-cycle is annual with a resting pupa from August to June.

Acronycta conjecturalis, A. fasciata and **A. sinens** feed on *O'ea dioica*. **A. pruinosa** feeds on *Elaeagnus latifolia*. The larva, 30 mm., is described by Gardner, 1941, fig. 22, p. 264. **A. rubiginosa** defoliates *Terminalia myriocarpa*. The larva is described *tit. cit.*, p. 264, fig. 20.

Aegocera venulia [fig. 156, No. 3, fig. 157, No. 34] feeds on *Boerhaavia* and *Trianthema*; the agaristine larva is described *tit. cit.*, p. 292.

The genus **Agrotis**

C u t w o r m s : Larvae of the subfamily Agrotinae belonging to the genera *Agrotis*, (*Rhyacia*), *Euxoa*, etc. are pests known as Cutworms or Surface Caterpillars, because they live on or just below the surface of the soil, whence they attack seedlings and low plants, cutting them off near the ground-level or defoliating leafy plants. There are several species of cutworms in India but the group has not been critically studied there as it has in other countries and little is known of the identity, distribution and food-habits of the various larvae. (see Gardner, 1941, *Ind. For. Rec.*, Ent., VI, No. 8, p. 265.) The name *Agrotis ypsilon* has been generally used to denote a cutworm in the plains of India and the term undoubtedly covers several species.

Agrotis C-nigrum, A. flammatra, A. ypsilon, Euxoa segetis and **spinifera** have all been recorded as pests in India, Burma, Ceylon. The following generalised life-history applies to all species.

Agrotis ypsilon, the Greasy Cutworm.

A polyphagous pest of agricultural and garden crops; and of nurseries and regeneration (artificial and natural) in forests. It is most injurious in nurseries of conifers and particularly to sowings of *Cedrus deodara*, which are damaged, i.e. cut off in March–April soon after germination. Every year thousands of plants in deodar seed-beds and in patch sowings may be killed by this process and only a few pieces of the cut plants may be eaten by the cutworms. The species is regarded as the worst pest of regeneration areas in the coniferous forests of the Punjab and United Provinces. In agricultural lands in the alluvial plains of India and Burma and particularly in riverain flood-areas cutworms cause serious losses; in older annual crops the cutworms climb the plants and feed on the leaves or gnaw the epidermis of the stems as do ordinary defoliating caterpillars. In dense populations cutworms become cannibals killing and eating each other; they also tend to migrate to less crowded areas but not in swarms like the army worms. In waste land the cutworms normally feed on a variety of weeds; stems of herbaceous plants in which woody tissues are extensively developed are avoided. This species of cutworm is consequenly well adapted for wide dispersal and survival under adverse conditions.

Life-history: The moth has the long, narrow forewings irregularly marked with shades of brown and three black dashes and the hind-wings pale or white. The forewings lap closely over one another rendering the moth inconspicuous on a background of soil; expanse $1\frac{1}{2}$ to 2 inches. They hide by day in cracks in the soil, under stones, leaves, &c. One female may lay as many as 2,000 eggs in small lots on the humus, stones, weeds, or other plants. Moist situations are preferred such as soil wet with melting snow and mud left by receding floods. Hatching takes place after 2–6 days. The young caterpillars or cutworms feed on dry leaves forming the soil-covering if fresh foliage is not available, but are also carnivorous, finding flesh nearly as palatable as green vegetation. They hide in burrows one to three inches deep in the soil during the day and emerge at night; young seedlings are cut through the stem at ground-level, or the buds and new leaves are cut off. They very rarely climb plants that are too large to be cut down. Some of the fragments are taken by the caterpillars into their burrows in the soil and there eaten. They are, however, very restless feeders and after cutting a plant will leave it and wander elsewhere. The full-grown larva is $1–1\frac{1}{2}$ inches long, the body of almost uniform width, smooth, with very short hairs, earth-coloured with white or black speckled markings and large, isolated, convex skin-granules. If disturbed it curls on its side into a **C**. After 20 to 35 days spent as a larva, pupation takes place in the soil in a chamber with smooth rounded walls. The pupal stage lasts from 10–30 days. The life-cycle is about seven weeks (varying from 5 to 9 weeks) with two broods in the cold weather in the plains. The seasonal history in the Himalayas is not known. There are probably four generations with hibernation as a pupa. The moth is occasionally a migrant. This cutworm is one of the most pernicious species found in the Himalayas and Indo-Gangetic plains, but is not known in Western and Southern India. It is also found in Europe, America, Africa, Northern Asia and Australia.

For control measures see section on cutworms, Part Two.

LITERATURE ON CUTWORMS:

Ceylon, Tea Research Institute, Bull. 3.

Dutt H. L., 1917, *Agr. Jl. Dept. Agr., Bihar and Orissa*, v, pp. 1-14. The greasy surface caterpillar; its life-history and seasonal history.

Gardner J. C. M., 1935, *Ind. For.*, LXI, pp. 327-329. Note on Cutworms damaging deodar seedlings.

— 1941, *Ind. For. Rec.*, Ent., VI, No. 8, p. 265 (larva).

Lefroy H. M., 1907, *Mem. Dept. Agr., Ind.*, I, pp. 169, 259-274

— 1937, *Mysore Agric. Calendar*, pp. 41, 45. A new method of controlling some important underground insect pests of crops.

Pal B. P., 1936, *Proc. Ind. Acad. Sci.*, III, 527-534, pl. xxiii-xxv, figs. 11. On the relation between the internal stem structure of certain varieties of gram (Cicer arietinum) and their resistance to cutworm attack.

Raina J.L., *Leaflet* No. 5, *Kashmir Govt.*, Surface Cutworm (in Urdu).

Stebbing E. P., 1911, *Ind. For. Mem.*, II, i, pp. 61-66, pl. xiii, figs. 3 *a b*.

Amyna natalis defoliates *Sida rhombifolia*; the larva, 22 mm., is described in 1941, *Ind. For. Rec.*, Ent., VI, No. 8, p. 272.

Amyna octo defoliates *Chenopodium album*, the larva, 23 mm., is described 1941, *tit. cit.*, p. 272.

Anigraea albomaculata feeds on *Bursera serrata* and *Garuga pinnata* in August, September, lightly connecting with silk or rolling the leaves. The pupal period is 10 days in August–October. Moth-expanse 22 mm.; larva 20 mm. (described by Gardner, 1941, *Ind. For. Rec.* Ent., VI, No. 8, p. 273, fig. 10.)

Anomis erosa attacks *Bombax malabaricum*, cotton, *Hibiscus*, *Kydia calycina*, *Thespesia lampas*, *Urena lobata*; a widespread species. Egg 4, larva 20–30, pupa 9–14 days in October and 16–21 days in November. The total life-cycle is thus 5–8 weeks. Caterpillar 25 mm. long, moth 38 mm.

Hutson J., 1927, *Dept. Agr Ceylon*, leaflet No. 47.
Gardner J. C. M., 1941, *Ind. For. Rec*, Ent., VI, No. 8, p. 287,

Anomis figlina defoliates *Grewia microcos*, and *G. tiliaefolia*.

Anomis fulvida feeds on *Cissampelos pareira*, *Hibiscus* sp., *Kydia calycina*, *Thespesia lampas* and *Urena lobata* and other Malvaceae. A widespread species in Asia. The pupal period is 8 to 12 days in August, September; larva 12–18 and egg 3 days; full-grown caterpillar 45 mm.; moth 54 mm. Characters are given in Gardner, 1941, *tit. cit.*, p 287.

A. indica defoliates *Bombax malabaricum*. **A. mesogona** feeds on *Lantana aculeata*, *Rosa* sp., *Rubus lasiocarpus*. The larva, 35 mm., is characterised in *tit. cit.*, p. 287.

Anomis sabulifera defoliates *Eriolaena hookeriana*, *Grewia elastica*, *G. laevigata*, *G. tiliaefolia*. It is a species of wide distribution and a pest of jute in the rains in India; the caterpillar is 40 mm. long, a semilooper, with one rudimentary and 2 abdominal and anal prolegs, green with 5 dark piliferous tubercles on each segment. Diagnostic characters are given in Gardner, 1941, p. 286. The moth is dull earth-brown coloured with darker spots and suffusion; span 32–38 mm.; several aberrations are named *bipuncta*, *costifusca*, *involuta*, *ruficlathrata*. The life-cycle takes about 25 days in the hotter weather, and hibernation as pupa occurs until May.

Anua triphaenoides feeds on *Eugenia jambolana* and *Shorea robusta*; the larva, 45 mm. long, is described in Gardner, 1941, p. 281.

Arsacia saturatalis defoliates *Dalbergia oliveri*.

Attatha regalis defoliates *Ficus religiosa*. The larva, 40 mm., is described in *tit. cit.*, p. 282.

Avitta quadrilinea feeds on *Alseodaphne semecarpifolia*.

Baniana divulsa feeds on *Dalbergia latifolia*.

Beara dicromella defoliates *Trema orientalis* and *Xylia dolabriformis*. **B. nubiferella** feeds on *Tectona grandis*; wing-span of moth 24–28 mm.

Bombotelia jocosatrix defoliates *Mangifera indica*, *Spondias mangifera*, *Terminalia belerica*. Caterpillar green with dark sublateral lines and purple spots; wing-span of moth 30 mm. **B. nugatrix** feeds on *Morus alba*. Pupal period 13 days in May in the folded spun leaf. Wing-span of moth 26–30 mm.

Calpe emarginata feeds on *Cissampelos parena*; pupal period 9–14 days in June–July; the larva, 45 mm., is described in *tit. cit.*, p. 285.

Caradrina plagiata feeds on *Grewia microcos* and *G. tiliaefolia*.

Carea chlorostigma feeds on *Eugenia jambolana* and *Memecylon edule*. Wing span of moth 28–36 mm.

Carea subtilis defoliates *Eugenia jambolana*, *E. jambos* and *Memecylon edule*. The larva has the body-colour light brown and the first thoracic segment green and swollen into a large ball so that the caterpillar might be mistaken for a spherical gall or a green berry fallen on the leaf; length ⅜ to 1¼ inch (*Ind. For. Rec.*, Ent., VI, No. 8, pp. 280, fig. 6). Pupation occurs in a thick silken cocoon. The life-cycle is about 24 days to a month in the hot weather, increasing from 30 to 42 days in September; caterpillars occur as late as December, the winter brood hibernating either as larva or as pupa. Moth with rusty brown forewings and white hindwings; expanse 1½ inches. (*Proc. Third. Ent. Meet.*, Pusa, 1919, I, pl. 10, *j*, *k*.). The young larvae eat the upper epidermis of the leaf in patches and do not destroy the lower surface; this produces conspicuous white patches on the dark green foliage. Older larvae eat holes.

Catephia linieola feeds on *Lagerstroemia flos-reginae*.

Chloridea see **Heliothis**.

Characoma ruficirra feeds inside fruits of *Juglans regia* attacked by *Alcides*; it also feeds on the foliage of *Quercus incana*; pupation occurs in June–July.

Chlumetia alternans and **C. transversa**. The larvae of these species bore into the shoot of *Mangifera indica* which dies back or does not flower subsequently; the larva also eats the young leaves and inflorescence. Wing-span of moth about 20 mm.

Churia nigrisigna defoliates *Grewia laevigata*. The larva, 22 mm., is characterised in Gardner, 1941, p. 279, fig. 8.

Cucullia verbasci, a European species extending to the Punjab, and feeding on *Verbascum thapsus*.

Cosmophila see **Anomis**.

Dichroma trigonalis feeds on *Boehmeria platyphylla*; pupa 10 mm.; moth wing-expanse 36 mm.

Dipthera champa feeds on *Prunus communis*, *Pyrus communis*, *P. puddum*, and *P. persica*. The pupal period in September is 9–12 days and from November is prolonged to March, 4 months. Wing-span of moth 44–58 mm.; larva 30 mm., *tit. cit.*, p. 264.

Donda ornata feeds on *Bombax malabaricum*. Pupation occurs in November and after hibernation and aestivation as pupa, the moth emerges in June.

Earias cupreoviridis feeds on *Grewia tiliaefolia* and *Sida rhombifolia*; the larva, 18 mm., is described by Gardner, 1941, *tit. cit.*, p. 276, fig. 21. **E. fabia** and **E. insulana** are the spotted bollworms of cotton in India. **E. fabia** is the more serious pest in the chief cotton-growing tracts of the country but is primarily a tropical species being most active in the hot season and neither hibernating or aestivating. Its threshold of development lies at about 12°C. and its upper vital limit at about 40°C. Under suitable humidity conditions 4 generations a year are possible at 16°C and 16 generations at 35°C. The preimaginal development and viability of *E. fabia* under different conditions of temperature and humidity have been determined by Tashkir Ahmad and Ghulam Ullah, 1939, *Ind. Journ. Ent.*, I, pp. 17–47.

Elydna plagiata defoliates *Grewia microcos*.

Ericeia inangulata defoliates *Cassia fistula*, *C. renigera* and *Xylia dolabriformis* in Burma. It occurs throughout India and extends to Africa and Australia Wing span of moth 50 mm.

Episparis liturata feeds on *Adina cordifolia* in the rains; the pupal period is 9 days in October. Wing-span of moth 40 mm. **E. tortuosalis** defoliates *Chickrassia tabularis* and *Michelia champaca* in Bengal. The larva, 40 mm., is described in *Ind. For. Rec.*, Ent., VI, No. 8, p. 240.

Eublemma abrupta feeds on flower buds, flowers and young fruits of *Lantana aculeata*; in India its usual food-plant is *Ficus gibbosa*.

Eublemma amabilis.

The moth is cream-white with the outer 2/3rds of the wings marked with various broad and narrow angulated bands of pinkish-violet, sepia, fuscous and ochreous and browns and white. The wing-expanse in the female is 20 mm., in the male 16 mm. The egg is spherical, yellow in colour. The mature larva is yellowish-white and about 14 mm. long; diagnostic characters are given by Gardner, 1941.

L i f e - c y c l e : The eggs are laid between the young lac larvae or on the outside of the older lac encrustation and the young caterpillar on hatching bites a hole in a lac cell and feeds on the lac insect within; from this cell it passes to others, boring its way through the adjoining wall and lining its tunnel with silk in which pink discs of excrement and fragments of lac resin are entangled. Before pupating it makes an exit-hole and closes it from below with a web of silk. A single *Eublemma* caterpillar during its life may destroy 40–70 lac insects and an appreciable portion of the lac formed by them. It moults 10 times.

The seasonal history in Central India normally comprises 6 generations in the year, the 1st commencing in the second half of

February and lasting about 70 days, the 2nd and 3rd in May to mid-July lasting about 35-40 days each, 4th and 5th into mid-October lasting about 45-50 days respectively. In warmer climates and seasons the hot weather generations may develop in as short a period as 30 days, but excessive heat is unfavourable and oviposition then ceases or is unproductive. The eggs laid by September or October moths give rise to larvae that normally hibernate until next February (i.e., a life-cycle of 150 to 170 days) but a small proportion gives rise to short-cycle larvae that may produce moths at any time throughout the cold weather. The eggs of these cold weather moths ordinarily do not survive, but sometimes produce intermediate broods taking 3 or 4 months to mature.

Each lac crop thus allows the development of 2 to 4 generations of *Eublemma* according to its season of swarming and harvesting. The Katki crop is attacked by 2 broods but the Baisaki by 3 or 4, of which the first during the cold weather months may be of very slight importance. The Aghani and the Jethwi crops are attacked by 3 broods. The predator occurs in greatest abundance in June–September and hence preponderates in the Aghani and Katki crops. When the stick-lac is collected from the trees and stored, the eggs, larvae and pupae of *Eublemma* are transferred with it and the development of the predator continues for several weeks. Moths may emerge from stick-lac in the hot weather for as long as 3 months and in the autumn for as long as 6 months after cutting.

Economic importance: This predator does more damage to the lac insect than any one other of its enemies and is probably responsible for the destruction of at least a third of the crop in normal years. It occurs throughout the lac-growing districts of India. Compared with *Holcocera pulverea* it is much more injurious to growing lac, and of about equal importance in stored stick lac.

Gardner J. C. M., 1941, *Ind. For. Rec.*, Ent., VI, No. 8, p. 271 (larva).
Misra, Negi and Gupta, *Journ. Bomb. Nat. Hist. Soc.*, XXIV, pp. 431-446.

Eublemma parva feeds on the flowers of *Blumea balsamifera* and on *Xanthium*. **E. silicula** feeds on the flowers of various plants and in inflorescences and fruits, also in witches-broom malformations of shoots. Larval characters are given by Gardner, 1941, *tit. cit.*, p. 271. **E. scitula** is predaceous on coccids including *Lecanium longulum*. The caterpillar lives in a case and several may congregate in groups on the stems of trees attacked by scale insects.

Eusemia adulatrix and **E. latimargo** feed on *Dioscorea pentaphylla*.

Eutelia favillatrix feeds on *Lannea grandis* in October–December. The pupal period lasts over one month in November, December. Wing-expanse 25-30 mm.

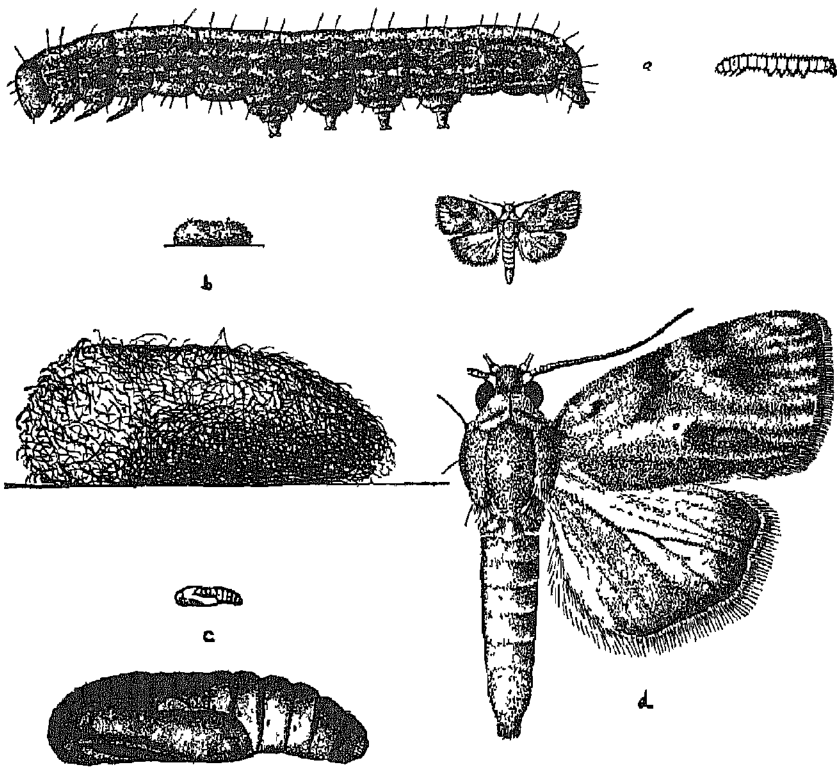


Fig 178. Giaura sceptica.

Euxoa segetis is one of the cutworms damaging coniferous seedlings (*Cedrus deodara*) in nurseries in the mountains but it also occurs below 2,000 ft. in south India. Wing expanse of moth 30–50 mm.; larval characters are given in *lit. cit.*, p 265. **E. spinifera** feeds on weeds and agricultural crops, the larval characters are given in *lit. cit.*, p 265.

Fodina stola feeds on *Anogeissus latifolia*, *Cassia fistula* and *Holarrhena antidysenterica*. The mature larva is about 40 mm. long, velvety black with broken longitudinal bands of yellow, dorsally and laterally; the head and last abdominal segment are yellowish-green. (see *lit. cit.*, p. 288). The pupa, 17 mm., is formed in soil and matures in 10–12 days in July. Moths of this generation continue to emerge until September. Moth, bright reddish brown forewing, orange and black hind-wing, expanse 35–45 mm

Gabala polyspilalis feeds on *Garuga pinnata*

Giaura niveidisca defoliates *Pterospermum semi-sagittatum*.

Giaura sceptica feeds on *Butea frondosa*, *Glycine hispida*

and *Grewia hainesiana*. The pale green larva, length 15 mm., spins a fine silk web under the shelter of which the leaves are eaten. The pupal period is 7 days in August and 8 or 9 days in September, October and is passed in a cocoon on the foliage or in a cell in the soil. The pupa is 10 mm. long; the moth has a wing-expanse of 20–22 mm. [fig. 178].

Fletcher T. B., 1919, *Agr. Res. Inst., Pusa*, Bull. No. 89, p. 63, fig. 37.

Grammodes geometrica is a widely distributed species, feeding on various shrubs and herbs and also on *Diospyros montana*. Moth wing-expanse 40–50 mm. **G. stolida,** another widespread species, feeds on *Zizyphus jujuba* and other plants of dry regions. Wing-expanse 30–45 mm.

Heliothis armigera (=obsoleta) is a pest in many parts of the world. The caterpillar, 35 mm., is a general feeder on agricultural and garden crops and ornamental flowering plants as well as the foliage of some trees. It is also predaceous on caterpillars of other smaller species, and often completes its life-cycle as a wholly carnivorous predator without further vegetable food; this is usually the case when *H. armigera* caterpillars, for various reasons, find themselves on an unpalatable food-plant. Larva 1¼ inches, moth wing-span 30–40 mm. About 8 generations a year with hibernation as pupa.

Chatterjee N. C., 1940, *Proc. 27th Ind. Sci. Congress*, II, p. 177.
Gardner J. C. M., 1940, *Ind. For. Rec.*, Ent., VI, No. 8, p. 273 (larva).

Hullodes drylla defoliates *Xylia dolabriformis* in Burma.

Hypena abyssinialis. This species occurs throughout India feeding on *Lantana aculeata* and *L. indica*. The egg hatches in 2, 3 days to 7–15 days. The larva is leaf-green in colour speckled sparsely with black dots; it is a semi-looper and when disturbed lets go its foothold, wriggles violently and throws itself from the leaf. It feeds in patches on the leaf, skeletonising the upper surface which turns whitish; flower-heads are eaten in preference to foliage. Pupation takes place in a silk cocoon in the soil with grains of earth attached. It is abundant during the monsoon season with a pupal period of 7 or 8 days, and continues active into the colder months.

Hypena aurotincta defoliates *Abrus precatorius*; the larva 22 mm., is described in *Ind. For. Rec.*, Ent., VI, No. 8, p. 291. **H. iconicalis** defoliates *Desmodium gangeticum*; the larva, 25 mm., is described in *lit. cit.*; the pupal period is 8 days in August. **H. ignotalis** feeds on *Lantana aculeata*. The pupal period is 7 to 8 days in September. The larva, 20 mm., is described in *lit. cit.*, p. 292, fig. 12.

Hypocala biarcuata defoliates *Diospyros montana*; wing-expanse 40 mm. **H. moorei** defoliates *Diospyros montana*; wing-expanse 45–55 mm. The larva is parasitised by one of the teak defoliator parasites. **H. rostrata** defoliates *Erioglossum rubiginosum*, *Diospyros ehretioides*, *D. melanoxylon*, *D. montana*, *D.*

tomentosa, *Glochidion lanceolarium*, *Spondias mangifera*, *Barringtonia acutangula*. Widely distributed. It is probably identical with *H. subsatura* The larva, 25 mm., is described in *tit. cit.*, p. 288, fig 3. The pupal period is 8 days in July–August; pupa 18 mm long. Moth violaceous grey, forewing with dark spot, hindwing orange, costal area dark brown, wing span 30–50 mm. **H. subsatura** is a defoliator of *Quercus dilatata*, *Diospyros montana* and *D. melanoxylon*. **H. violacea** defoliates *Diospyros candolleana*.

Hypoglaucitis benenotata feeds on *Dalbergia sissoo*.

Hypotrisula boarmioides on *Grewia tiliaefolia*.

Ingura subapicalis is a defoliator of *Shorea robusta* and *Tectona grandis*. Outbreaks of it frequently occur in the sal forests of the United Provinces and Central Provinces. The caterpillar (about one inch long) is smooth bodied, straw-coloured with a pink suffusion at the fore and hind ends. [fig. 156, No. 25]. Diagnostic characters are given in *tit. cit.*, p. 274 The cocoon is disguised with larval excrement. The moth (expanse $\frac{3}{4}$ inch) has the forewing violaceous brown and the hindwing pale with a dark outer border. [fig 157, No. 9]. The first generation appears when the sal comes into leaf in May, and is completed in June (pupal period one week), it is usually much more abundant than the later generations of the rains and winter. The young foliage particularly is attacked and in bad outbreaks the trees may be completely stripped.

Laphygma exigua a cosmopolitan pest of annual crops which are attacked when young by swarms of caterpillars. Life cycle about 3 weeks with hibernation as a pupa

Lophoptera costata feeds on *Mallotus philippinensis*. **L. illucida** feeds on *Bridelia retusa* and *Shorea robusta*.

Lyncestis amphix feeds on *Cordia myxa*, *Ehretia laevis* and *Ocimum canum*.

Maurilia iconica feeds on *Anogeissus acuminata*, *A. latifolia*, *Shorea robusta*, *Tectona grandis*. It is responsible for severe defoliation of sal plantations in Bengal. The larva, 25 mm, is described in *tit cit*, p 277. The pupa is a rather thin cocoon formed on a twig or leaf

Miselia consanguis defoliates *Elaeodendron glaucum*.

Odontodes aleuca feeds on *Shorea robusta*. The pupal period is 11 days in July.

Ophideres ancilla defoliates *Achyranthes aspera* and *Tiliacora acuminata*, the velvety black, blue speckled caterpillar is a semi-looper, $2\frac{1}{2}$ inches long.

Ophideres fullonica. The caterpillar is a semi looper with only 4 pairs of prolegs, the first being absent. The ground colour is dark olive green with pinkish suffusion; two pairs of conspicuous eyespots, white with a black centre in which is a white speck, occur dorsolaterally on the 2nd and 3rd abdominal

segments; there are 8 black longitudinal lines, one dorsal, 3 lateral, one ventral; a dorsal protuberance occurs on the last segment. Diagnostic characters are given in *tit. cit.*, p. 288 (*Othreis*). When disturbed the caterpillar doubles up the fore half of its body and lifts up the hind half in a roughly **S** shaped position. The full-grown larva is 2½ inches long. It feeds on climbers of the Menispermaceae chiefly, *Cocculus laurifolius*, *Cyclea peltata*, *Tiliacora acuminata*, *Tinospora cordifolia* also *Stephegyne diversifolia*. The larval period is about 6 weeks and the pupal period 2 weeks. The moth is a pest of citrus fruits which it punctures, sucking the juice. Head and thorax red-brown suffused with plum colour; forewing red-brown with contrasted markings; hindwing orange with large black markings.

Ophideres materna. The larva feeds on *Tinospora cordifolia* and the moth sucks citrus fruits. The larva is greyish-brown profusely speckled with yellow and blue, over 2 inches long; pupa 1 inch long.

Ophiusa tirrhaca feeds on *Shorea robusta*, *Terminalia belerica*, *T. tomentosa*.

Pandesma quenavadi defoliates *Acacia catechu* and *Xylia dolabriformis*. The larva, 35 mm., is described in *tit. cit.*, p. 289, fig. 19. **P. spissa** defoliates *Xylia dolabriformis*. **P. umbricola** defoliates *Salix tetrasperma* in Burma.

Parallelia crameri feeds on *Phyllanthus emblica*.

Pasipeda haemorrhoa feeds on the leaves of *Barleria cristata*. The larva, 45 mm., is described in *tit. cit.* The cocoon is made of soil-particles lightly bound with silk.

Pericyma glaucinans defoliates *Albizzia amara*. **P. umbrina** defoliates *Acacia catechu* and *A. suma* in India and Burma. The larva, 35 mm., is variable in colour from much black to nearly entirely green (see *tit. cit.* p. 282); the pupal period is 10–14 days during the monsoon season.

Phelegotonia delatrix feeds on *Eugenia jambolana*. In September the pupal period is 11–13 days.

Phytometra chalcytes feeds variously, including *Lantana aculeata* and *Solanum pubescens*; the larva, 25 mm., is characterised in *tit. cit.*, p. 284. **P. nigrisigna.** The caterpillar is a semi-looper and feeds on various garden and field-crops; it occurs on *Cannabis sativa*, *Chenopodium album* and other weeds in the undergrowth of shisham plantations.

Phytometra orichalcea. The semi-looper caterpillar is about 1½ inches when full-grown, narrowed anteriorly, pale green to dark bluish-green in colour with narrow white lines on the dorsum and a white line and black-centered white spots on the sides. The pupa is dark reddish-brown, naked, 3/4rs of an inch long; pupation occurs in the soil. It is a widespread minor pest of garden and field crops and feeds on various weeds including *Cannabis sativa*; also on *Butea frondosa*, *Dalbergia sissoo*, *Mussaen-*

da lutea, *Eugenia jambolana*. The caterpillar is active during the cold weather and spring and does not hibernate; the pupal period is 10 days at the end of March, and 8 days in April in north-west India.

Lefroy H. M., *Mem. Dept. Agr., Ind.*, I, p. 193.
Fletcher T. B., 1914, *Some South Indian Insects*, p. 393, fig. 260.
Gardner J. C. M., 1941, *Ind. For Rec.*, Ent., VI, No. 8, p. 284 fig. 16. (description of larva).

Plecoptera reflexa

Moth, [fig. 157, No. 4], forewing greyish-brown with oblique irregular bands, underside greyish-white, expanse 1¼ inches. Caterpillar, a semi-looper, smooth, cylindrical, green with 8 white lines down the back; the mature caterpillar, one inch, changes to pinkish. Pupa, dark brown, ⅜rs inch. Egg, pale green, circular, domed, 0·75 mm. Distributed throughout India with *Dalbergia sissoo*; a serious pest in the irrigated plantations of the Punjab and occasionally responsible for epidemic defoliation elsewhere. Also recorded as a pest of *Dalbergia latifolia* and *Pterocarpus marsupium*.

Life-history: The moths are nocturnal hiding during the day in low vegetation and dead leaves, and swarming in the early evening. Eggs are laid during the night on young leaves, usually one egg only per leaf. Each female may lay up to 400 eggs and starts within 24 hours after emergence; oviposition may last for 6 days. Hatching takes place in 1 to 5 days. The very young caterpillar eats the lower epidermis and inner tissues of the leaf leaving the upper epidermis intact. Young foliage is essential to the young larva and on old foliage they develop very slowly or fail to survive. The later instars consume the whole leaf and avoid mature leaves, but will eat leaf-petioles and green shoots. About 50 square inches, or 10 to 20 grains, of foliage are destroyed by one caterpillar, the quantity eaten per day increasing rapidly after the second instar. When disturbed the caterpillar drops at the end of a silk thread. On the ground it wriggles violently and throws itself about when touched; it travels rapidly over the soil and plants and reascends a tree. In epidemic defoliation, when the foliage has been completely destroyed, large armies of caterpillars may be seen moving over the ground in search of fresh food.

The larval period varies with temperature from 10 days in the hottest weather to 13 days in spring and 20 days or more in autumn. It is longer on old foliage than on young foliage. The larva undergoes 5 moults. Pupation takes place on the ground among leaves or rubbish or in loose soil; a pupal cell of silk and particles of soil, etc., is usually constructed. The pupal period lasts 5 to 7 days in hot weather and 8 to 11 days in autumn. Hibernation takes place in the pupal stage and lasts for 80 to 100 days. In the Punjab plains there are eleven generations a

year on the average, the length of the life-cycle varying from 17 to 30 days and that of the hibernating life-cycle being about 140 days. At a quicker rate of development as many as 13 generations occur within the year. At Dehra Dun there are 10 generations a year, the length of the life cycle varying from 19 to 32 days.

The first generation moths appear at the end of March and the beginning of April in the Punjab plains, which appearance is sometimes in advance of the leafing of shisham. At Dehra Dun moths have emerged in the second week of March. Defoliation by the first broods is generally not noticed. Forest officers usually describe heavy defoliation as beginning at the end of April and continuing to the end of August in three phases which are referred to (erroneously) as generations. Actually there are 6 or 7 generations in this period. The mortality in all stages of the insect increases when the atmospheric humidity rises during the rainy season, and natural control is sufficient from September onwards to prevent further epidemics. The last broods go into hibernation in October.

Economic importance: In the Punjab damage by this species was first recorded in Changa Manga in 1899; in Chichawatni and Khanewal it appeared when the plantations were three years old and has recurred in abundance annually ever since. It established itself equally early in the life of the later plantations. Recent serious epidemics occurred in 1927, 1928 and 1932 and contributed to the final destruction of moribund compartments.

"The cumulative effect of defoliation in backward crops is disastrous. The trees are stripped of their leaves and remain leafless for the greater part of the growing season. After repeated attacks the affected trees present the appearance of dying tips and leading shoots. A crop of epicormic branches is produced and ultimately the trees succumb to the attack" (*Irrigated Plantations Manual*, 1932, p. 83). Large areas of poor quality shisham have in consequence been abandoned or converted. The loss is equivalent to Rs. 20 to 40 per acre and has been so extensive as to affect fundamentally the policy of management and the practice of irrigation and silviculture in the plantation districts.

In natural stands of pure shisham *P. reflexa* rarely occurs in sufficient abundance to destroy the foliage and in the later transition stages of riverain forests of mixed shisham it is never a pest. Roadside and canal bank and avenue shisham often suffer severe defoliation.

For control measures see Part Two.

LITERATURE:

Beeson, 1938, ***Ind. For. Rec.***, Ent., IV, No. 1, pp. 8-13, Guide to the insects of Dalbergia sissoo.

Kashyap R. N. and Mattu M. L., 1930, ***Ind. For.***, LVI, pp. 253-255, Shisham defoliator in Khanewal plantation. — , pp. 389-396, Abandoned areas *in Khanewal plantations.*

Singh B., 1932, ***Irrigated plantations in the Punjab.*** A manual of all operations.
— 1935, ***Ind. For.***, XLI, pp. 453-460, Theory of irrigation as applicable to the Punjab irrigated plantations.

Prodenia litura.

Economic importance: This widespread species is a very general feeder on agricultural and garden crops and a pest particularly of cotton and tobacco. The Royal Agricultural Society of Egypt in 1936 offered a reward of £ E. 20,000 for the invention of a method of preventing this species from attacking the cotton plant in Egypt. Among forest trees and shrubs attacked by it in India are *Cassia tora*, *Diospyros montana*, *Lantana*, *Randia dumetorum*, *R. uliginosa*, *Solanum indicum*, *S. torvum*, and *Tectona grandis*.

When feeding on teak, of which one to three year old plants are sometimes affected, the older leaves are preferred. The whole of the leaf-surface including the veins is eaten and the thicker parts of the midrib and leaf-stalk are tunnelled into. Complete defoliation of young regeneration areas has been recorded in April, May, particularly after accidental fires and near *taungya* cultivation.

Life-history: Eggs are laid in a mass on the under surface of the foliage, and the egg-clusters are covered with scales from the tip of the abdomen of the female moth. The fecundity is very high. The caterpillars are dull olive green with light side stripes, slender towards the head end. Diagnostic characters are given by Gardner, 1941, *tit. cit.*, p. 267. When in motion the forepart of the body is swayed from side to side with a leech-like effect. The full-grown caterpillar is about $1\frac{3}{4}$ inches, 45 mm., long. Pupation occurs in the soil at a depth of down to two inches in a loose cocoon. The moth has the forewings greyish-brown, delicately marbled or streaked with fine silvery lines on the apical half; the hind wings are pearly white. Wing-expanse about $1\frac{1}{2}$ inches. The life-cyle is 4 to 8 days for the egg-stage, 3 to 4 weeks for the larva, 1 to 4 weeks for the pupa, which allows a sequence of over five generations per annum in South India. Caresche states there are 8–10 generations a year in Tonkin and 11–12 in Cochin China.

LITERATURE:

Caresche L., 1937, ***Bull. econ. Indochine***, XL, pp. 517–537, 3 pls.
Ramakrishna Ayyar T. V., 1931, ***Agr. Dept. Madras***, Bull. 26, p. 1 (figs.)
— 1933, ***tit. cit.***, Bull. 34, p. 7 (figs.)
Gardner J. C. M., 1940, ***Ind. For. Rec.***, Ent., VI, No. 8, (larva).

Pseudelydna rufoflava feeds on *Terminalia myriocarpa* and *T. tomentosa*. The larva, 35 mm. long, is very similar in structure to *Carea subtilis* with a thoracic swelling which decreases prior to pupation; it is described by Gardner, 1941, *tit. cit.*, p. 280. The pupa is formed in a cocoon densely woven, tapering

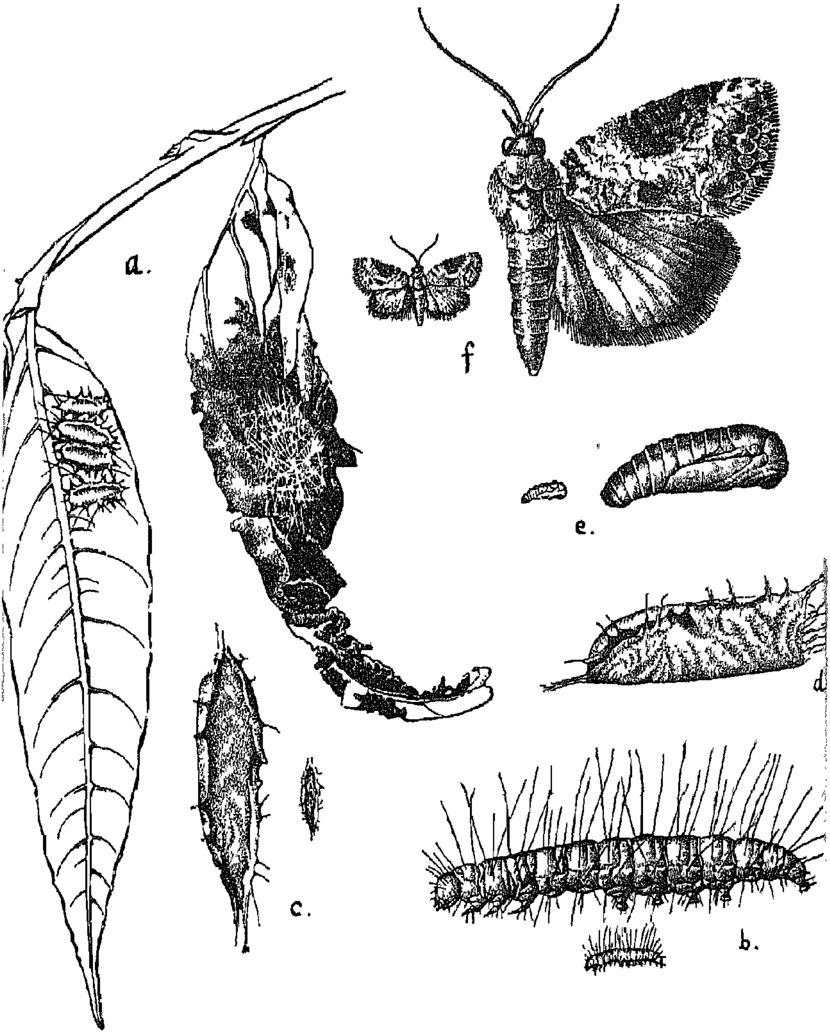


Fig. 179. Symitha nolallela on Lagerstroemia.

at one end and truncate at the other; pupal period 8–10 days in June–July.

Rhesala imparata defoliates *Acacia suma, Albizzia lebbek* and *A. procera*; it is troublesome in plantations in the Andamans. The larva, 20 mm., is described in *tit. cit.*, p. 291. **R. inconcinnalis** defoliates *Albizzia procera* from September; pupation occurs in November with moths in January.

Risoba obstructa is a defoliator of *Lagerstroemia flos-reginae*,

Terminalia paniculata, *T. tomentosa*, and *Xylia dolabriformis*. The larva, 20 mm., is described in *tit. cit.*, p. 277. The slender fusiform cocoon is attached along a twig.

Selepa celtis. This widespread species occasionally causes complete defoliation of various species of trees. The larva, 16 mm. long, is yellow with a black spot on the 2nd and 7th and a black dot on the 8th and 9th abdominal tergites and is sparsely clothed with very long pale hairs. Characters are given by Gardner, 1941, *tit. cit.*, p. 276, figs. 4, 5. The pupa is formed in a cocoon of excrement. The moth [fig. 157, No. 11] has greyish-brown forewings with a dark spiral line in the middle; expanse nearly 1 inch. *S. celtis* has 5 or 6 generations a year in north and central India. There is a cold weather brood after the rains which pupates in November or December and has a variable cocoon-period (2 weeks to 2 months) with moths at any time up to March. The life-cycle is 3-4 weeks in September. Other generations produce moths in April, May and in August, and in September. Eggs laid in November do not produce a brood. When feeding on large leaves the midrib and stouter side-veins are left untouched.

The trees attacked are *Bischoffia javanica*, *Careya arborea*, *Elaeodendron glaucum*, *Ficus glomerata*, *Gmelina arborea*, *Duabanga sonneratioides*, *Lagerstroemia flos-reginae*, *Lannea grandis*, *Mangifera indica*, *Mussaenda frondosa*, *Nephelium litchi*, *Schleichera trijuga*, *Stereospermum suaveolens*, *Shorea robusta*, *Terminalia catappa*, *T. chebula*, *T. myriocarpa*, *T. tomentosa*, *Xylia dolabriformis*.

Selepa docilis defoliates *Solanum melongana*, *S. torvum* and *S. xanthocarpum*. The larva, 13 mm., is described by Gardner, 1941, *tit. cit.*, p. 276.

Spirama retorta feeds on *Albizzia lebbek*.

Stenopterygia subcurva defoliates *Ochna squarrosa*; the larva, 25 mm., is described by Gardner *tit. cit.* p. 270.

Symitha nolalella feeds on *Lagerstroemia flos-reginae* and *L. lanceolata* by spinning together the leaves [fig. 179].

Fletcher T. B., 1919, *Agr. Res. Inst. Pusa.*, Bull. 89, p. 63 fig. 36.

Trigonodes regalis feeds on *Sterculia villosa*.

Westermannia coelisigna defoliates *Terminalia belerica*. The larva, 30 mm., is described in 1941, *tit. cit.*, 280. Pupation occurs in an earthen cocoon thinly bound with silk.

Zalissa albifascia feeds on *Leea sambucina*.

NOTODONTIDAE

Hampson G. F., 1892, *Fauna Brit. Ind.*, Moths, I, pp. 124-177, figs. 72-109, Notodontidae.

Cerura liturata feeds on *Casearia tomentosa*, *Glycosmis pentaphylla*, *Homalium tomentosum*, *Flacourtia inermis*, *Terminalia tomentosa*; pupal period in July, 23 days. The caterpillar

has a pair of blunt spines on the thorax and a pair of long tapering processes with small spines which are on the last segment.

Chadisra bipars defoliates *Xylia dolabriformis.*

Desmeocraera fasciatus feeds on *Quercus semecarpifolia*; at high elevations moths occur from April to July.

Dudusa nobilis feeds on *Schleichera trijuga* eating mature foliage. Pupation occurs in the soil in October–January with moths in June.

Bell T. R. D., 1935, *Journ. Bomb. Nat. Hist. Soc*, XXXVIII, pp. 134, 136, pls. 2.

Gargetta costigera defoliates *Bridelia retusa*, pupating in the soil and emerging in August–September after a pupal period of 12–16 days. The caterpillar is rather slender and has a pair of blunt spines on the pronotum and two long filamentous processes on the last segment.

Hupodonta excurvata defoliates *Anogeissus latifolia.* Pupation takes place in the soil in a tough cocoon thickly covered with adherent earth. From pupae of July, moths emerge in 2 or 3 weeks or may pass a whole year in a diapause. The full-grown caterpillar is 30 mm. long, pink, with a pair of short spines on the pronotum, a long curved spine on the 1st abdominal segment and 3 small spines on the 8th abdominal segment.

Phalera goniophora and **P. raya** defoliate *Quercus serrata* in Burma. **P. parivala** feeds on *Lespedeza thompsoni.*

Pygaera cupreata defoliates *Salix tetrasperma.* **P. fulgurita** defoliates *Elaeodendron glaucum, Salix tetrasperma* and *Xylosma longifolium*; the pupal period is a week to 10 days in May, June.

Stauropus alternus. The Lobster Caterpillar.

This species is a general feeder occuring on *Acacia catechu, A. dealbata, A. decurrens, Amherstia nobilis, Albizzia stipulata, Cajanus indicus, Camellia theae, Cassia fistula, C. javanica, Grevillea robusta, Mangifera indica, Ougeinia dalbergioides, Tamarindus indica, Trewia nudiflora, Xylia dolabriformis,*

Life-history: The caterpillar has a large head and large pointed tubercles on each side of the dorsal surface of the metathorax and the abdominal segments of which the last 2 or 3 are expanded at the sides into a flange; the terminal abdominal segment is swollen and bears a pair of slender curved appendages instead of anal claspers; the legs are long and slender, the first pair very much shorter than the other two pairs; clasping legs are present on the 3rd to 6th abdominal segments. The colour is variable, brownish tinged with green, or grayish-black with black patches, or mottled light and dark brown, speckled finely with white dots and more or less pubescent. The 6th instar or full grown caterpillar is 1½ to 2 inches long. The larvae are restless but when disturbed or excited assume a threatening

attitude that has earned them the inappropriate name of 'lobster caterpillar'. The head and front part of the body are raised and curved backwards and the end of the abdomen is raised (including the hind-most pair of claspers) so that it almost touches the head. The four long thoracic legs are stretched forwards or spread apart and quiver whenever the body is moved convulsively. The terminal appendages are directed backwards. This contorted shape may easily be mistaken for a piece of dry crumpled leaf or similar debris, but when recognised as a caterpillar it may be at once identified as a species of *Stauropus*.

The larval period occupies from 4 to 5 weeks and the total life-cycle lasts from 6 to 8 weeks in south India. Pupation takes place in yellowish-brown loosely woven cocoons formed between 2 or 3 leaves spun together, or placed unprotected on twigs. There is a prepupal period of 2–3 days and a pupal period of 9–13 days.

The moth is pale grey suffused with darker shades and a marginal row of reddish-brown and pale spots on both wings. Expanse 1½ to 2½ inches. The moths rest with the forewings closed in over the abdomen so that the hindwings are exposed in front of the apical margins of the forewings.

Susainathan P. and Sundaram, C.V., 1921, *Rep. Proc. Fourth Ent. Meet.*, Pusa, 1921, pp. 291-292, Life history note on Stauropus alternus.
Hutson J. C., 1932, *Trop. Agr.*, LXXVIII, No. 6, pp. 327-336, pl. IX, The lobster caterpillar.

Stauropus inclusus feeds on *Quercus griffithii*.

Stenadonta radialis defoliates *Dendrocalamus strictus* in the monsoon; the pupal period is 6–7 days.

NYMPHALIDAE

THIS family (including the Danainae and Satyrinae) is one of the largest of the Butterflies. Many species feed on forest trees but none have so far been recorded as regular pests. The butterflies are true sun-lovers and consequently the dominant types are familiar objects, e.g., the Admirals, Tortoise-shells, Fritillaries and the Map and Leaf Butterflies.

LITERATURE ON NYMPHALIDAE.

Bell T. R. D., 1909-1910, *Journ Bomb. Nat. Hist. Soc*, XIX, 39-58, pl E, 438-474, pls I, F, 635-682, pl. II, 846-879, XX, pp. 279-326.
Bingham C. T., 1905, *Fauna Brit. Ind*, Butterflies I, pp. 1-478, figs. 86, pls. 1-10 (coloured), Nymphalidae.
Evans W. H., 1927, *The identification of Indian butterflies*, pp. 88-125, pls. 17-25.

Attela phalanta feeds on *Salix tetrasperma*; the pupal period is about 3 weeks in November.

Charaxes fabius sulphureus feeds on *Wagatea spicata* and *Xylia dolabriformis*. **C. imna** feeds on *Saccopetalum tomentosum*.

Cirrochroa thais feeds on young leaves of *Hydnocarpus wightiana*.

Cyrestis thyodamas feeds on most species of *Ficus*.

Danais chrysippus, which is one of the commonest Indian butterflies, feeds on *Calotropis gigantea* and *C. procera*. It is a regular migrant.

Danais limniace mutina feeds on *Holarrhena antidysenterica*.

Delias descombesi feeds on *Lagerstroemia tomentosa*. **D. eucharis** feeds on *Loranthus cordifolius* and *Pterospermum acerifolium*.

Discophora celinde feeds on coconut palm and bamboos.

Dophla evelina laudabilis on *Anacardium occidentale*, *Diospyros melanoxylon* and *D. candolleana*.

Elymnias undularis feeds generally on palms.

Ergolis ariadne feeds on *Ricinus communis*, *Tragia cannabina* and *T. involucrata*.

Eriboea arja feeds on *Tectona grandis*.

Eulepis athamas on *Albizzia julibrissin*, *A. lebbek*, *Acacia catechu*, *A. caesia*, *A. pennata* and *Poinciana regia*.

Euploea core is a common species feeding on various species of *Ficus*, *Holarrhena*, *Nerium* and *Streblus asper*. It is a regular migrant.

Lethe drypetis on *Bambusa arundinacea*. **L. incana** on hill bamboo, *Arundinaria falcata*.

Neptis jumbah on *Bombax*, *Dalbergia*, *Elaeocarpus*, *Grewia*, *Pongamia*, *Trema*, *Xylia* and *Zizyphus*, etc.

Telchinia violae defoliates *Vitex pinnata*.

Vanessa cardui, the Painted Lady, feeds on a great variety of of herbs and shrubs including *Artemisia vulgaris*, *Blumea* sp., *Coricus arvensis* and *Zornia diphylla*. It is one of the most widespread butterflies and is a regular migrant in Europe, North America and India.

Yoma sabina vasuki on *Pandanus actorius* and *P. tectorius*.

OECOPHORIDAE

A FAMILY of Microlepidoptera which includes shoot-borers, defoliators and leaf-webbers.

Fletcher T B, 1921, *Mem. Dept. Agr. Ind.*, vi, pp. 105-112, pls. xxiv, xxv.
— 1933, *Imp. Counc. Agr. Res., Sci. Mon.*, No. 4, pp. 8-13, pls. vii-ix (Oecophoridae).

Allotalanta triocellata. The larva bores the young shoots of *Anthocephalus cadamba* feeding on the central woody tissue and ejecting the frass through a hole in the side of the twig. The pupal period is about two weeks at the end of March.

Cryptolechia arvalis spins together the leaves of *Careya arborea*. **C. sanctificata** defoliates *Flemingia paniculata*, **C. nyctiphronas** webs together leaves of *Barringtonia acutangula* in twos and threes and feeds inside.

Eucleodora coronis feeds on *Aspidopterys wallichii*.

Tonica niviferana. The Semul Shoot-borer [fig. 180]. This

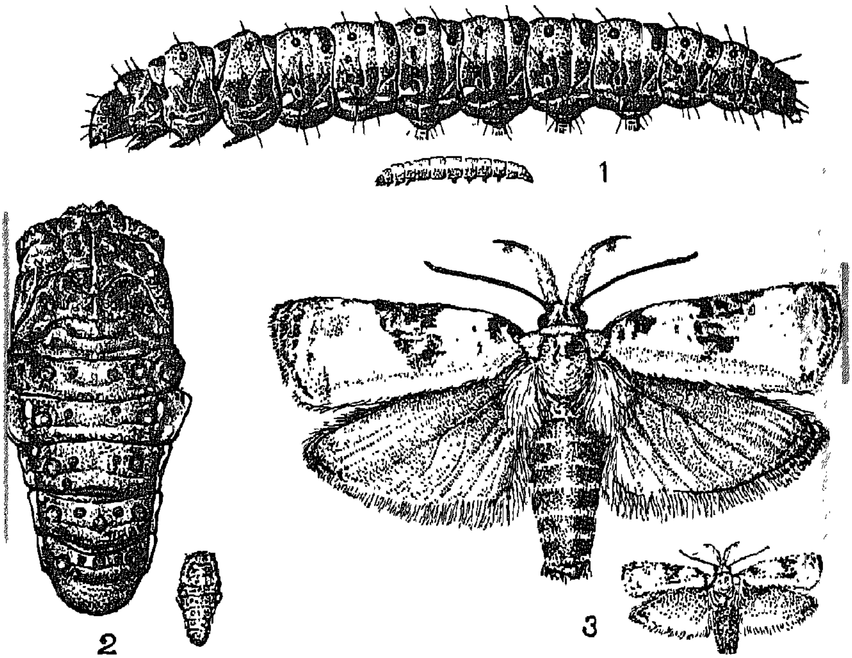


Fig. 180. Tonica niviferana, Oecophoridae.

species is a borer of young shoots of *Bombax malabaricum* and a pest in semul plantations. The young larva bores into the thickness of the new shoot at a leaf-axil under the shelter of a web of silk threads. As it grows it excavates a tunnel down the centre of the shoot and may completely hollow out and kill a thick stem down to the old wood of the previous year. The tunnel is filled with the black larval excrement and fragments of frass, gum, etc. are extruded through an ejection-hole to remain as a blackish mass readily detected at a distance. The young larva is brownish-yellow; the mature larva, nearly one inch long, is orange-yellow with black dots above and greyish or black along the sides and under surface [fig. 180]. For pupation it leaves the tunnel and transforms openly on the leaf or stem of the plant; the pupa, about 12 mm. long and half as broad, is brownish-grey, roughened, (like a Lycaenid butterfly pupa) and is attached by the cremastral hooks to a network of silk on the leaf.

The moth [fig. 180] has a wing-expanse of $1\frac{1}{2}$ inches, the forewings white with dark patches, the hindwings yellow; when resting with the wings closed it resembles a bird's dropping.

There are two generations in the year in north India with moths emerging in the hot weather in March–May (mainly April) and again in July–October, mainly August (pupal period one to

two weeks, mode 7 days). In November the caterpillar leaves the tunnel in the shoot and bores into the thick bark at the base of the tree and forms chambers in which it passes the winter and hot weather, emerging at the end of March to pupate exposed on the surface of the stem. The pupae are often highly parasitised.

For control measures see Part Two.

Fletcher T B, 1917, *Proc. Second Ent. Meet*, *Pusa*, p. 131 (coloured plate).
— 1921, *Mem Dept Agr. Ind.*, VI, pp. 106-108, pl xxiv, (coloured).
— 1933, *Imp Counc Agr. Res., Sci. Mon*, No. 4, p. 11, pl. IX.

Macrobathra notomitra. The larva binds together and feeds on the leaflets of *Acacia catechu* so that a cluster of partly eaten and dry leaflets is formed; pupation occurs in the larval shelter in a flimsy cocoon. The pupal period is about 7 days in June but may extend to 4 months hibernation in the cold weather. The stages of the insect are figured by Fletcher, 1933, *tit. cit.*, pl. vii.

Species of **Promalactis** breed under the bark of logs of trees.

Psorosticha zizyphi feeds on the foliage of *Aegle marmelos*, *Citrus* spp., *Feronia elephantum*, *Glycosmis pentaphylla*, *Murraya koenigii*. When young the larvae mine the leaves but after a short time they either tie up several apical leaflets together longitudinally or roll up a single young leaf by turning over the edge on to the blade and feed from within the roll; young tender leaves are always selected (Fletcher). The full-grown larva is 15 mm. long; pupation in a cocoon within rolled leaves. In Ceylon the average life-cycle takes 24 days.

Fletcher T. B., 1921, *Mem. Dept. Agr. Ind.*, VI, No. 4, p. 108, pl. xxv.
Hutson J C., 1934, *Trop. Agric*, LXXXIII, pp. 191-193, coloured plate, 8 figs. The citrus leaf-roller.

PAPILIONIDAE

SWALLOWTAIL Butterflies include species feeding on trees and palms.

Bell T R. D., 1911-1912, *Journ. Bomb. Nat. Hist. Soc.*, XX, pp. 1115-11136, pl. DI. DS XXI, pp. 517-544, pls. D2—D4, pp. 740-766.
Evans W. H., 1927, *The identification of Indian Butterflies*, pp. 25-39, pls. I-VI.
Talbot G., 1939, *Fauna Brit. India*, Butterflies, I, pp. 54-300, figs. 11-107, pl. I, Papilionidae.

Chilasa clytia lankeswara defoliates *Alseodaphne semecarpifolia*, *Cinnamomum zeylanicum*, *Litsaea sebifera*, *Machilus gamblei*, and *Phoebe lanceolata*; the form **onpape** feeds on *Sarcosperma arboreum*. The butterfly resembles a *Euploea* or *Danais* in its dark and light forms respectively. The stages are described by Bell, 1912, *tit. cit.*, pp. 532–537, pl. 1.

Graphium agamemon feeds on *Michelia champaca*, *Polyalthia* spp. and *Saccopetalum tomentosum* in south India. The larva and pupa are described by Ayyar T. V. R., 1939, *Journ. Bomb. Nat. Hist. Soc.*, XLI, pp. 443–445. **G. doson axion** feeds

on *Cinnamomum* spp., *Michelia oblonga, Polyalthia* sp. and *Saccopetalum tomentosum.* **G. nomius swinhoei** feeds on *Pandanus tectorius, Polyalthia longifolia* and *Saccopetalum tomentosum.* **G. sarpedon** feeds on *Alseodaphne owdenii, Camphora officinalis, Cinnamomum* sp., *Litsaea* sp. and *Machilus odoratissima.* The pupal period is about 3 months in the cold season, the butterflies emerging in March. The larva is described by Bell, 1911, *tit. cit.*, pp. 1115–36.

Papilio demoleus demoleus. The caterpillar when young is dark brown with white speckling and closely resembles a bird-dropping; it becomes bright green and straw-coloured with brown and white margins in later stages. The larva is described by Bell, 1911, *tit. cit.*, and Sevastopulo D.G., 1939, *tit. cit.*, XLI, pp. 311–312. Pupation occurs openly on the plant, the pupa suspended by a girdle. It is a pest of lemon, orange and lime trees destroying the foliage and shoot-tips. Other food-plants are *Acronychia laurifolia, Aegle marmelos, Chloroxylon swietenia, Feronia elephantum, Glycosmis pentaphylla, Murraya koenigii, Psoralia corylifolia, Ruta angustifolia, R. graveolens, Triphasia trifoliata* and *Zizyphus jujuba.* It frequently migrates in large swarms.

Polydorus aristolochiae defoliates *Aristolochia* spp. and *Dioscorea wallichii.*

PIERIDAE

Bell T. R. D., 1912-1914, *Journ. Bomb. Nat. Hist. Soc.*, XXI, pp. 1131-1157, pls. 1, 3, XXII, pp. 92-100, 320-344, 517-531, pls. K, L, XXIII, pp. 73-103.

Evans W. M., 1927, *The identification of Indian Butterflies*, pp. 40-54, pls. VII-IX.

Talbot G., 1939, *Fauna Brit. Ind.*, Butterflies I, pp. 300-563, figs. 108-184, Pieridae.

Anapheis aurata feeds on *Capparis aphylla, C. heyneana, C. sepiaria, Cadaba indica, Jasminum pubescens,* and *Maerua arenaria.* (Previously known as *Belenois mesentina.* Bell, 1912, p. 1153, pl. 1, fig. 60, life-history).

Appias libythea olferna defoliates *Capparis sepiaria* and *Crataeva roxburghii.*

Catopsilia crocale and C. pyranthe.

These closely allied and very similar species are common sulphur-yellow butterflies in India and most of the Oriental Region and are pests of various species of *Cassia.*

C. crocale feeds on *Bauhinia racemosa, Butea frondosa, Cassia auriculata, C. fistula, C. javanica, C. occidentalis, C. siamea* and *C. tora.*

C. pyranthe feeds on *Cassia auriculata, C. occidentalis, C. tora* and *Sesbania grandiflora.*

Life-history: The butterfly of each species has a wing expanse of 2 to 3 inches (50–75 mm.) [fig. 156, No. 14]. The

female lays singly on leaves white spindle-shaped eggs which turn yellow before hatching. The larva is bright green or bluish-green with a dark dorsal line and a spiracular broad white line suffused with yellow on segments 2 to 5; the back and sides are covered with small black or green tubercles. The full-grown larva [fig. 157, No. 15] is 40 mm. long. The pupa is green to greyish-brown with some yellow lines, length 23-28 mm.; it is formed suspended from a leaf or twig. Life-cycle about 30 days.

These *Catopsilias* are pests of *Cassia fistula* and *C. siamea* in plantations and rabs; serious damage has been recorded in Assam, Coorg and Madras. The defoliation of the young plants may cause the annual death or malformation of the leading shoots. There are several generations in the year taking 3 to 4 weeks but they do not necessarily follow in sequence in one and the same place. Both species of *Catopsilia* migrate annually and the flights take place at several seasons in the year. Migrating swarms are never dense but there are always hundreds of individuals in view. The butterflies keep to the wing during sunshine and settle immediately the sun is obscured. (These flights occur annually at Dehra Dun). Records of migration in India are given by C.B. Williams, 1938, *Journ. Bomb. Nat. Hist. Soc.*, XL., pp. 439-457. Apart from the migratory swarms these butterflies are markedly gregarious and assemble in countless numbers on moist soil in order to drink. For life-history and descriptions of the stages see Bell, 1913, pp. 517-520, pl. L, figs. 72, 73.

Catopsilia pomona feeds on *Cassia fistula*; it is also a migrant and widespread from India to Australia.

Eurema blanda silhetana. The caterpillars of this butterfly feed on various species but mainly Leguminosae—*Acrocarpus fraxinifolius, Albizzia lebbek, A. stipulata, A. moluccana, Cassia nodosa, Gliricidia maculata, Poinciana regia, Sesbania aculeata, Wagatea spicata, Xylia dolabriformis.*

Life-history: The oval white eggs pointed at the upper end are laid in clusters of 20 to 50 on the under surface of new leaves, being attached by one end so that they stand out nearly erect. The butterfly tends to fly low and oviposits generally on plants below 15 feet high, but, when ovipositing on climbers like *Wagatea spicata*, may be seen high in the air round the tree tops. The larvae are gregarious feeders stripping the leaf to the midrib. Colour of the larva green with a pale lateral stripe and a black head; length one inch. The pupa is jet black, triangular and flattened, attached to the plant by the tip of the abdomen and a fine silk thread around the middle. The pupae are assembled in conspicuous clusters and may be mistaken for a bunch of seed capsules or fruits. When there is a heavy attack the caterpillars migrate to other plants for the purpose of pupating in the foliage. The butterfly is bright yellow with a black border to the wings which is broadest at the apex of the forewing but is very variable;

expanse $1\frac{1}{2}$ to 2 inches. It is distinguishable from the commoner *Eurema hecabe* by the presence of an extra spot in the cell on the underside of the forewing.

There are several generations in the year with greatest abundance in June to October. At low levels in the south the life-cycle is about one month with a larval period of 14 to 16 days. Above 4,000 feet the life cycle lasts 40 to 50 days with a larval period of 25 to 30 days. The butterfly often migrates in vast swarms.

Economic importance: The butterfly is a serious pest of young plantations of *Acrocarpus fraxinifolius* in Bengal, Madras and Ceylon. It is probably the species responsible for severe defoliation of young *Albizzia lebbek* in the Andamans. For control measures see Part Two.

Bell T. R. D, 1913, *Journ Bomb Nat Hist Soc*, XXII, pp 530-531
Hutson J. C, 1932, *Trop Agric*, LXXVIII, p. 131, Insect pests and green manuring

Eurema hecabe feeds on various agricultural leguminous crops, also on *Acacia* spp., *Albizzia procera*, *Caesalpinia*, *Cassia* spp., *Sesbania*, *Pithecolobium dulce* and *Wagatea* sp.

Terias see **Eurema.**

PSYCHIDAE

PSYCHIDAE are a small family with several unique characters. The larvae are Bagworms living inside portable but cumbrous bags made of silk open at both ends and covered with pieces of vegetable matter such as leaves and twigs [figs. 156, No 31 and 181]. The male moth is highly specialised with broadly bipectinate antennae, an elongate extensible abdomen, and wings built for rapid and prolonged flight. [fig. 157, No 24]. The female moth is very degenerate, wingless, and, in extreme forms, the antennae, legs and mouthparts are entirely absent.

Life history. The larva on hatching from the egg has a tendency to wander and climb up to the tops of shrubs and trees in order to reach the tips of the growing shoots When it settles and begins feeding it constructs a small tough bag of silk of cylindrical or conical shape on the outside of which are gummed small fragments of plant tissue. The young bagworm carries its first bag upright, but in the later instars the bag is too heavy and is carried in a pendent position. Various materials are used to cover the outside of the bag depending on the species of Psychidae and the species of plant on which it is feeding Many species feed on *Acacias* and use the leaflets and long spines [fig 156, No 31] and pieces of slender twigs [fig. 181], those feeding on *Casuarina* use the branchlets, those on large leafed trees use large pieces of leaf or the leaf-stalks and stems; on pines and other trees pieces of bark are used.

The caterpillar keeps its body inside the bag and, when

moving about, the head and thorax are protruded so that it walks on its thoracic legs dragging the bag behind it, which is gripped by the hooks on the abdominal prolegs. When at rest it attaches the rim of the bag to a twig by means of silk cords so that it hangs suspended; the caterpillar retires inside the bag and draws together the mouth entirely closing it.

From time to time as the bagworm grows in size it needs to increase the size of the bag. In the case of species feeding on *Acacia* and using cut pieces of twigs to cover the bag the procedure is as illustrated in fig. 181, A,B,C. Before cutting through the twig the larva attaches the rim of the bag with silk to the twig just below the place where the cut is to be made and takes up its position on the piece that is to be cut away as shown in fig. 181, A. The groove is gradually gnawed all round until the twig is severed, when the larva falls clinging to it but is brought up short by the suspensory cord of silk attaching the bag to the uncut end of the branchlet. Fig. 181, A shows the cutting of a piece of twig that will be used for the adornment of the bag, the distal portion having been previously cut off and discarded.

Hanging by the suspension, as shown in fig. 181, B, the larva proceeds to prune the twig of any leaflets or side shoots on it, turning and twisting it for the purpose by means of the thoracic legs. It also gnaws off and eats the thin outer rind. When the piece of twig is properly trimmed it is temporarily glued by one end to the rim of the bag and the larva retires within the bag. From the inside it now cuts away the silk and old twigs making a hole at a quarter of an inch or so below the mouth of the bag. Pushing out its head and thorax through this new hole it takes up the freshly cut twig and, cutting it loose, turns it about until it is placed with its tip in the required spot between the ends of other twigs, as shown in fig. 181, C.

The caterpillar now withdraws inside the bag again and closes the hole with a fresh patch of silk that fixes the twig firmly at the top end. When sufficient twigs have been cut and attached the caterpillar working from the inside bites away the wall of the bag along the length of one of the old twigs which is cut loose and discarded. The new twig is pulled into place to fill the slit and fastened along its whole length with fresh silk. By this means the whole of the old bag is gradually destroyed and replaced piecemeal with new work. Some of the old twigs may be retained and built in with the new work, or everything may be ejected through the bottom aperture of the bag. When the bagworm is full-grown it suspends the bag from a twig, closes the mouth and turns so as to face head downwards towards the bottom aperture. Fresh silk is spun as an inner lining to the bag and the larva then pupates.

The pupa of the male moth pushes its way down through the opening at the bottom of the bag and when about half its length

expanse $1\frac{1}{2}$ to 2 inches. It is distinguishable from the commoner *Eurema hecabe* by the presence of an extra spot in the cell on the underside of the forewing.

There are several generations in the year with greatest abundance in June to October. At low levels in the south the life-cycle is about one month with a larval period of 14 to 16 days. Above 4,000 feet the life-cycle lasts 40 to 50 days with a larval period of 25 to 30 days. The butterfly often migrates in vast swarms.

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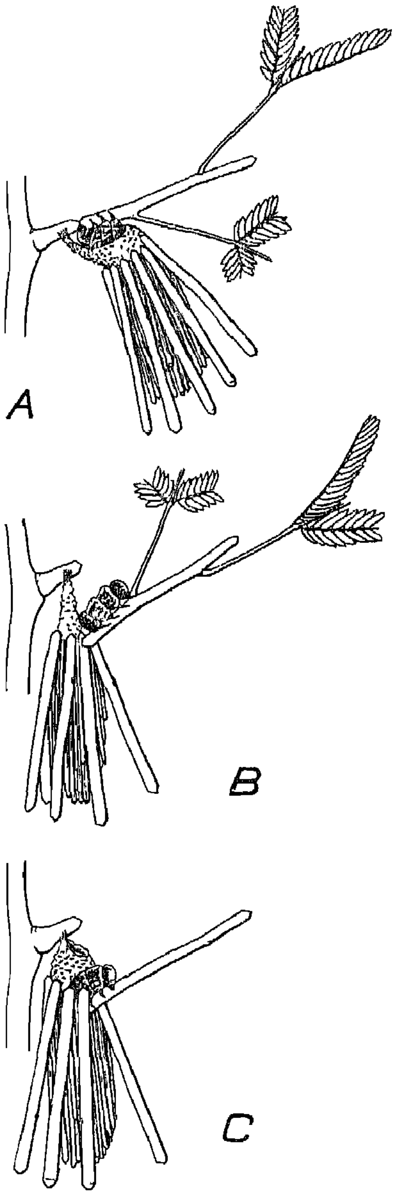

Fig. 181. Clania cramerii. The bagworm cuts off and trims twigs to enlarge its bag; see pages 666-668.

is exposed the moth emerges; the pupal skin remains sticking out of the bag. The female insect does not completely emerge from the pupa but remains inside the bag partly covered by the split pupal skin, where she is found by the male. The male inserts its whole abdomen inside the bag and by greatly elongating it passes it inside the female pupal skin until the apex of the abdomen of the female is reached and pairing follows. Eggs are laid by the female to the number of several hundreds in the pupal skin until the bag is almost filled with eggs. She then forces herself out of the bag and falls to the ground to die. The life-cycle is usually annual in most parts of India.

Economic importance: Bagworms are injurious by reason of the foliage they eat and the damage is greatly increased by the pruning off of twigs or growing shoots, buds, etc., required in making the bags. In selecting one twig of the right diameter and length the bagworm may cut off the whole leading or lateral shoot and discard the unwanted portions. Twigs may be strangled by the silk girdle made for the suspension of the bags of hibernating larvae and females.

Hampson G H., 1892, *Fauna Brit. Ind*, Moths 1, pp. 289-304, figs. 198-208. Psychidae.

Acanthopsyche moorei is found on *Lagerstroemia indica*. **A. subteralbata** defoliates species of *Albizzia* in Ceylon.

Chalia doubledayi feeds on *Cassia fistula*. **Chalioides vitrea** on *Grewia hirsuta*.

Clania cramerii is an important polyphagous bagworm found

throughout India.

There is some doubt as to the specific name of this bagworm, and whether the forms that feed consistently on one food-plant should be considered biological races or species; they are, however, polyphagous under stress of necessity.

Life-history: The male moth is reddish-brown streaked with black; the middle of the forewing is semi-transparent; expanse $2\frac{1}{2}$ inches. [fig. 157, No. 24]. The female is without visible wings or legs, resembling a grub (about $\frac{3}{4}$ inch long) rather than a moth, and does not leave the larval case. Fertilisation takes place by the insertion of the much elongated abdomen of the male into a case containing a female. Eggs (50 to 500) are laid in the case from December onwards or between February and April according to the climate of the locality. The larvae emerge after two or three weeks and take nine or ten months to mature. The young larva forms a protective covering of moss, hairy leaf-epidermis, particles of bark, etc., interwoven with silk. At later moults new cases are formed or enlarged by using pieces of twigs [fig. 181], leaf-stalks, acacia thorns [fig. 156, No. 31], etc., or of whole leaves. The twig-cases are almost cylindrical while those formed of leaves are more or less conical. The process of constructing a new case is described on pages 666-668 and fig. 181. The mouth of the case is of flexible silk that can be withdrawn to close the opening. The mature larva, 1-$1\frac{1}{2}$ inches, is smooth-bodied, in colour brown or purplish with the thorax marked with lighter streaks. Before pupation the case is suspended from a twig and closed and the larva turns with head towards the bottom opening. The male pupa pushes out through the bottom end of the case and the moth escapes from the half-emerged pupa.

The life-cycle in most parts of India is annual with moths appearing early in the year from cold weather pupae, but development may be irregular with two generations in north-west India, the second producing moths in August.

Economic importance: The bagworm feeds on *Acacia arabica*, *A. catechu*, *Albizzia* spp., *Alseodaphne semecarpifolia*, *Antigonon leptopus*, *Artemisia vulgaris*, *Bischofia javanica*, *Bombax malabaricum*, Camphor, *Cassia*, *Casuarina equisetifolia*, *Eugenia* spp., *Lagerstroemia indica*, *Litsaea polyantha*, *Santalum album*, *Shorea robusta*, *Tamarindus indica*, Tea, *Terminalia chebula*, The damage due to feeding is increased by the pruning of leading shoots and twigs required for forming cases. The plantations of *Casuarina equisetifolia* on the Orissa, Madras and Malabar Coasts are badly affected every year. The same or an allied species also feeds on *Pinus longifolia* using bark-fragments for its case.

The larva and male pupa are described by D. G. Sevastopulo, 1939, *Journ. Bomb. Nat. Hist. Soc.*, XLI, p. 318.

PTEROPHORIDAE see page 694.

PYRALIDAE

FROM the Indian region some 1,500 species of PYRALIDAE have been recorded many of which feed on forest trees and at least three are pests of first rank; several are pests of agricultural crops. Feeding-habits include true leaf-eaters, skeletonisers, leaf-rollers, shoot-borers, seed and fruit-borers. Among these are numerous forest-inhabiting species which are of ecological importance in so far as they are the alternative hosts of parasites and part of the food-supply of predators of pests of trees. Life-cycles vary from 1 to 15 per annum and most species have several generations a year.

Hampson G. F., 1896, *Fauna Brit. Ind.*, Moths IV, pp. 1-449, figs. 1-239, Pyralidae.

Acharana mutualis is a defoliator of *Solanum giganteum*, *S. indicum*, *S. melongana* and *S. torvum*.

Aetholix flavibasalis defoliates *Duabanga sonneratioides*.

Agathodes ostentalis feeds in the young leaves of *Erythrina lithosperma* under the protection of a fine web. The life-cycle is 5 or 6 weeks.

Agrotera basinotata occasionally occurs as a defoliator of *Eugenia operculata*, *Lagerstroemia flos-reginae*, *L. lanceolata*, *L. parviflora*, and *Pavetta indica* in the early part of the year and in the rains. The leaves are folded together for shelter and for pupation. The pupal period is about a fortnight in the hot season; the cold season is passed in either the larval or the pupal stage prolonged for 50 to 80 days. **A. scissalis** defoliates *Eugenia jambolana*; the pupal period is two weeks in March.

Argyria fuscivenalis defoliates *Crataeva religiosa*.

Cherian M. C., 1934, *Journ. Bomb. Nat. Hist. Soc.*, XXXVII, pp. 692-696, 7 figs.

Balanotis rhodoptila feeds on the leaves of *Chickrassia tabularis*.

Bombotelia jocosatrix feeds on *Mangifera indica*.

Bostra vibicalis defoliates young plants and saplings of *Shorea robusta*. A smooth black caterpillar which hides during the day among dead leaves, etc. on the ground and climbs the plant to feed at night; the leaf is wholly eaten; pupal period 2 weeks in September.

Botyodes asialis, widely distributed in Asia, is a defoliator of *Casearia graveolens*, *C. tomentosa*, *Diospyros tupru*, *Glycosmis pentaphylla* and *Urena lobata*, in October, November. The pupal period is 12 days in October and as much as 19 days in November. **B. caldusalis** rolls the leaf of *Michelia champaca*.

Calamochrous pentasaris defoliates *Dendrocalamus strictus* in September; pupal period 8 days.

Caprinia conchylalis feeds on *Alstonia scholaris*, *Funtumia elastica*, *Holarrhena antidysenterica* and *Wrightia tomentosa*, folding and skeletonising the leaves.

Cateremna pinivora feeds on the needles of *Pinus excelsa*.

Cateremna tuberculosa feeds as larva in galls on the leaves of *Dipterocarpus tuberculatus* in the monsoon.

Chalcidoptera appensalis feeds on *Combretum extensum*.

Chalcidoptera straminalis is a defoliator of *Shorea robusta* primarily and of *Lagerstroemia flos-reginae*. A generation is active in June and others occur during the monsoon. The pupal period in September is 6 days and in October is 7 or 8 days. Caterpillars from moths of the latter generation feeding in November, December produce moths in the cold weather which are darker coloured than the monsoon race. The pupal period in the cold weather lasts one to two months.

Conogethes discinotalis defoliates *Grewia disperma*. **C. nigrilinealis** defoliates *Bombax malabaricum*, *Cordia myxa*, and *Kydia calycina*. **C. plutusalis** defoliates *Croton oblongifolius*, *Grewia microcos*, the pupal period is about a week in August. **C. pyrrhalis** defoliates *Grewia asiatica*, *G. tiliaefolia*.

Cotachena histricalis defoliates *Celtis* sp.; the pupal period is 6 days in July.

Crocidophora ptyophora lives inside the leaves of bamboo rolled into a cylindrical case and tied with silk threads. After eating the inner layers the larva pupates in a cocoon covered with a layer of chewed leaf. The larva is about ½ inch long and the moth has a wing expanse of one inch.

Ctenomedes neuractis defoliates *Casearia graveolens* and *Elaeodendron glaucum*. The pupal period is 30 to 40 days in January-March after a long larval period.

Cybolomia nemausalis defoliates *Crataeva unilocularis*; pupal period about 10 days in July.

Deba surrectalis defoliates *Cassia fistula*; the pupal period is one week in October.

Dichocrocis leptalis bores in the fruits of *Pentacme suavis*. The larva is shown in fig. 156, No. 26. **D. evaxalis.** [fig. 157, No. 3, moth], India to New Guinea, bores in fallen fruits of *Dillenia indica* the moth emerging in October-May. The length of the larval period varies within wide limits, the latest individuals not pupating till March. In September the pupal period lasts 9 days, in October 18 days, in April 12-14 days Pupation usually occurs in the soil in a flimsy cocoon which is enclosed inside another cocoon of thick tough sheet silk. **D. festivalis** defoliates *Grewia tiliaefolia*.

Dichocrocis punctiferalis is a widespread general feeder that is frequently a pod-borer and stem-borer attacking pods and seeds of *Elettaria cardamomum*, *Psidium guava*, *Ricinus communis*, *Tectona grandis*, *Theobroma cacao*, also fruits of mulberry, pomegranate, peach, sunflower, etc. and boring the shoots or stems of *Curcuma longa*, *Zinziber officinale*, and in galls of Psyllidae on *Garuga pinnata*, and *Mallotus philippinensis* and in cecidomyid

galls on teak stems. It is recorded as destroying about 70 percent of stored teak seeds in Burma; one larva feeds on a number of seeds boring into the core of each and then transferring to another seed. In Java it is recorded as killing leading shoots of teak, mining the terminal buds and the thick bases of the main ribs of young leaves (1922, *Tectona*, XV, pp. 944–950). When boring shoots and fruits of castor the caterpillar ejects masses of frass and silk webbing. *D. punctiferalis* is not regarded as a regular pest in teak plantations; its abundance is probably determined by the occurrence of field-crops and taungya. The moth is orange-yellow, spotted with black on both wings; expanse 24–32 mm.; the caterpillar, 20 mm. long, is reddish-brown, speckled with black warts; pupation in a white cocoon. A coloured plate is issued by the Agricultural Research Institute, India.

Dichocrocis surusalis feeds on *Grewia microcos.*

Dioryctria abietella is a borer of the cones of *Abies pindrow, A. spectabilis, Cedrus deodara, Picea morinda, Pinus excelsa, P. gerardiana, P. longifolia* in the western Himalayas between 6,000 and 9,000 feet and also of other species of conifers in Europe and North America.

The moth has the forewing grey mottled with black, expanse 25 to 35 mm.; the eggs of the first generation are laid early in spring on young cones. The larva bores tunnels through the scales and seeds destroying the latter and causing the subsequent growth of the cone to be checked or distorted. Attacked cones remain on the branches or fall at irregular times according to the amount of internal destruction; the scales do not open; a certain amount of resin and excrement in large pellets appears on the outside of the cone. The larva varies in colour from reddish to greenish with a black head, one inch long when mature. Pupation occurs in papery silk cocoons in the cone, or in soil from fallen cones, and moths emerge from July onwards through the monsoon season and again next year in the spring from hibernated larvae. In some years considerable damage is done, almost all the seeds of seedbearers being destroyed.

Euzophera cedrella is a borer of the cones of *Cedrus deodara, Picea morinda, Pinus excelsa*, and *P. gerardiana.* The moth has the forewing dark grey mottled with black, wing-expanse about 20 mm. The life-history is similar to that of *Dioryctria abietella.* **E. niveicostella** bores the fruits of *Aegle marmelos*; the moth emerges in May.

Glyphodes bicolor defoliates Apocyanaceae, *Alstonia scholaris, Carissa carandas, Ougeinia dalbergioides.* It is the alternative host of 1 species of parasite attacking teak defoliators. **G celsalis** defoliates *Olea dioica.* **G. conclusalis** defoliates *Cassia fistula* and *Cryptolepis buchanani.* **G. punctiferalis** defoliates *Sarcocephalus cordatus* and *Stephegyne diversifolia.*

Hapalia aureolalis defoliates *Gmelina arborea*, rolling up the

leaves and pupating in the rolls. **H. incoloralis** defoliates *Calotropis gigantea* and *Perzularia extensa*. **H. maindronalis** defoliates *Premna barbata*; pupal period 1 week in July.

Hapalia machaeralis, The Teak Skeletoniser

H. machaeralis is distributed with the teak forests of Ceylon, India, Burma, Indo-China and throughout the Malayan Region to Australia. *Tectona grandis* is the chief food-plant. *Callicarpa arborea*, *C. cana*, *C. macrophylla* and *Tectona hamiltoniana* serve as alternative food-plants.

Moth: [fig. 157, No. 13]. Forewing bright yellow with fulvous or pink transverse markings in the form of zigzag or serrate lines; hindwing pale with an ochreous or reddish marginal line or band. The pattern and colour of the markings are very variable and seasonal (see below). The middle tibia of the male is dilated and grooved; the groove contains a dense tuft of numerous fine grey scent-hairs which are normally completely concealed. The abdomen of the female is thicker and blunter than in the male and has only 6 abdominal segments visible ventrally (male 7). Wing-expanse 21-26 mm. male, 19-24 mm. female.

Seasonal forms: The variation in the colour-pattern is due to temperature and humidity and not to the quality of the food. They can be classified roughly into light varieties and dark varieties which characterise moths emerging in the hot seasons and the colder seasons respectively (with intermediate forms in the transition periods):—

1. *Dry hot season*: Forewing pearly white to dilute yellow with very indistinct zigzag lines; hindwing paler without any marginal border of pink.
2. *Wet hot season*. Forewing pale to ochreous-yellow with distinct orange or pinkish zigzag lines; hindwing paler with slightly darker marginal suffusion.
3. *Cool spring and autumn seasons*: Forewing ochreous-yellow with bold reddish or crimson zigzag lines and rose-pink outlines of the veins; hindwing yellowish-white with a crimson serrate marginal line.
4. *Cold season*: Forewing ochraceous suffused with pink, the costal zone dark brown, the zigzag transverse lines crimson externally, dark brown internally; hindwing yellowish, darker towards the margin, the marginal serrate line boldly crimson.

No. 1 is the palest form and No. 4 the darkest. In south India (Nilambur), where there is no dry hot season and no winter, forms 1 and 4 are very rare. At Dehra Dun and in Assam form 4 characterises the winter. In the Central Provinces forms 1 and 2 are prevalent. Light forms have been produced experimentally at high temperatures and dark forms at low temperatures from the same ancestors.

Larva: The 1st instar larva, 2 mm., is greenish-white with a light brown head; in the next instars 2 pairs of black dots are visible on each body-segment on a greenish-brown ground; in the 4th instar longitudinal bands of brown, yellow and green appear at the sides. The 5th instar, 22-25 mm. long with head-capsule 1·6 mm., is similarly coloured at first, with the 4 black dots with inconspicuous hairs and framed in a white or yellow rectangle on the dorsum of each abdominal segment; later the body-colour changes from green to brown or purplish. The anal claspers or false legs are conspicuous, projecting and diverging [fig. 156, No.

24]. Pupa: 10–13 mm. × 2·2–3·2 mm., reddish-brown. Egg: 0·75 mm.

Life-history

Sexual proportions: Females usually predominate in wild populations and are often twice as numerous as males. In Burma a female-dominant strain of *machaeralis* exists which, when bred in the insectary for several generations, becomes 100 percent female. Neither artificial environment or in-breeding is the reason for this tendency.

Oviposition: Moths shun light and hide during the day in shaded places in the undergrowth, especially dead leaves on the ground. At night they swarm in the crowns of teak trees or fly across country in search of fresh breeding-places. Long sustained flights are necessary to reach isolated and scattered teak trees which are repopulated every year. As the average life is long (30 days is possible), presumably visits to flowers or sap or water are essential from time to time. Mating takes place the night after emergence and is rarely postponed to the 3rd night; ordinarily one mating suffices to fertilise a female for the whole oviposition-period. Eggs are first laid 1–4 days after pairing. The maximum number of eggs produced by one female is 550, the normal is about 250; the oviposition-period lasts for a week or two (17 days maximum). Eggs are laid singly on the upper or under side of the leaf and hatch in 3 days more or less.

Larval habits: The first instar larva feeds on the superficial cells of the epidermis of the leaf under the protection of strands of silk spun in an open web; when the food accessible from this shelter has been consumed a new one is constructed elsewhere. In the 3rd instar the larva can bite right through the leaf and in this and subsequent instars it eats out the tissue between the network of veins, thereby skeletonising the leaf which turns brown. All parts of the leaf attacked are uniformly skeletonised and a pattern so produced is characteristic of the mature work of *machaeralis*. Other species of defoliators in their early stages skeletonise a teak leaf in much the same way (see illustrations in the comparative diagram of feeding-patterns of teak defoliators in Part Two, section *Hyblaea puera*) but these species consume the leaf wholesale in their later stages, whereas *machaeralis* does not. The later instars of *machaeralis* use a shelter-web combined with an escape-hole that enables the larva to retreat immediately to the opposite side of the leaf and drop by a thread of silk. Moulting takes place under the web.

Pupation: The mature 5th instar larva pupates on a green teak leaf or on undergrowth or in fallen leaves, spinning a thick opaque shelter-web in two layers criss-cross; at regular distances round the edges small oval holes are left (about 15–20) and an emergence-hole is provided at one end. Before pupating a thin

lining of fine silk is added as a third layer inside. The finished web measures about 18×30 mm. and is constructed in 2 or 3 hours. In regions with a winter climate the prepupal stage is prolonged during the period of hibernation; when the teak leaves fall at the end of the growing-season, hibernating larvae remain in their shelters on the dead dry leaves on the ground. At Dehra Dun this period may last for 5 or 6 months; in south India there is no hibernation.

Life cycles and generations

SOUTH INDIA

The ecology of *Hapalia machaeralis* in south India was studied at the F. R. I. insectary at Nilambur, Madras, at different seasons in several years.

Egg: The period of incubation is 2 or 3 days, the normal mode throughout the year being 3 days.

Larva: The larval period on *Tectona grandis* varies from 8 to 27 days (individual minimum and maximum); from February to June the monthly mode is 12 days; for the rest of the year 13 or 14 days except in November and December when the mode reaches a maximum of 20 days (see table page 676). There is no hibernation of the larva.

Pupa: The pupal period varies from 4–11 days (individuals); the monthly mode is shortest, 5 days, in March–May and longest, 8 days, in December and for the rest of the year is 6 or 7 days.

Pre-oviposition: For most of the year the monthly mode is 3 days and in June, July is 4 days.

Life-cycle: The life-cycle from egg to emergence of the moth varies from 14–41 days (individual minimum and maximum) and from 20 in March–May to 31 in December (monthly modes). The total life-cycle from egg to egg varies from 17–45 days (individuals) and from 23–24 days (monthly modes). Monthly variation of the stages in the life-cycle is given in detail in the following table which shows the seasonal sequence of generations through the year. Theoretically, it is possible for a series of 14 complete generations with a partial 15th to occur in one year. The quickest development takes place in March–May and the slowest in November–December. The effect of quality of the food on the rate of larval growth does not vary proportionately with the temperature. Compare the periods for *Hyblaea puera* given on page 609, which also has 14–15 generations a year but differs considerably in its rate of growth. Compare also the slower rate of development in Burma (13 generations) and in north India (10 generations).

Theoretical sequence of generations of Hapalia machaeralis on Tectona grandis in an average year at Nilambur, Madras, India.

Days from January 1.	Month	Incubation	Larval period	Pupal period	Pre-oviposition	Generation	Total life-cycle	Days from January 1.
31	January	3	14	7	3	1	27	27
		3	13	6	3	2	25	52
59	February	3	12	6	3	3	24	76
90	March	3	12	5	3	4	23	99
120	April	3	12	5	3	5	23	122
151	May	3	12	5	3	6	23	145
		3	12	5	3	7	23	168
181	June	3	12	6	4	8	25	193
212	July	3	13	7	4	9	27	220
243	August	3	13	7	3	10	26	246
273	September	3	14	7	3	11	27	273
304	October	3	13	7	3	12	26	299
334	November	3	15	7	3	13	28	327
		3	18	7	3	14	31	358
365	December	3	20	8	3	15	partial	

NOTE: The sequence of generations is assumed to start with moths emerging on the 1st of January and to continue without interruption during the leafless period (on adventitous foliage). Fourteen full generations are possible at the average rate of development in an average year and a fifteenth is partially completed by 31st December.

COORG

In an insectary at Tithimatti, south Coorg, the development of *H. machaeralis* on teak in June, August and September was—incubation 3, 3, 3, 3; Larva 18, 19, 20, 20; Pupa 9, 10, 10, 9; Pre-oviposition 5, 6, 6, 5; Life-cycle 35, 38, 38, 37 days respectively for the monthly modes. The rate of development in the cooler climate is slower than at Nilambur and Dehra Dun. The mode of the pupal period in October and November is 9, in

December 11 and in January 12 days and the larva does not hibernate although the life of some individuals is considerably prolonged.

BOMBAY

At an insectary at Palghar, North Thana, Bombay, the monthly mode of the pupal period is: May 4–5, June 4, August–October 6 days. The individual range during this period is 3 to 11 days.

CENTRAL PROVINCES

In an insectary at Rahatgaon, Hoshangabad, C.P., the development during the months of July, August and September was—incubation 3, 3, 3; Larva 12, 14, 14; Pupa 5, 6, 6,; Pre-oviposition 4, 3, 3; Life-cycle 24, 26, 26 days respectively for the monthly modes. The rate of development differs very slightly from that in south and north India during the monsoon.

NORTH INDIA

Haldwani, U. P—At an insectary maintained at Dolpokhra, Chakata Range, Haldwani, the development of *machaeralis* in May, June was—Incubation 3, 3, 3; Larva 12, 13, 12; Pupa 5, 5 5; Pre-oviposition 3, 4, 4; Life-cycle 23, 25, 24 days respectively.

Dehra Dun, U. P.—Egg: The period of incubation is in April 4, May to September 3, October 4, and November 5 days respectively.

Larva: The individual larval period on teak varies from 8 days to 5 months; the monthly mode for April and May is 12 or 13, June 12, July 12–14, August and September 13, October 14 days respectively; between November and March the larva hibernates; this period of inactivity usually lasts 140–150 days with extreme minimum of 90 days and maximum of 180 days (see table page 678).

Pupa: The pupal period varies from 4–27 days; the monthly mode in March may be prolonged to 15 days; in April it is 6 or 7, in May to September 5 or 6 and in October 7 days respectivly. A late larva pupating at the end of October may have the pupal period prolonged to 27 days.

Moth: Unlike the moth of *Hyblaea puera*, that of *machaeralis* does not hibernate in a cold climate; the pre-oviposition period varies from 3 to 5 days being shortest in April–June and August, September (monthly mode 3 days).

Life-cycle: The life-cycle from egg to emergence of the moth varies from 15 days to over 6 months; the monthly modes vary from 20 days in May, 21 in June–August, to 24 at the ends of the actual season. The normal hibernating life-cycle takes 150–160 days, October–March. The total life-cycle within the active season, i.e., including the pre-oviposition period, ranges from 18 days (individual minimum) and 23 days (monthly mode) in May to a mode of 28 days in October and April. Monthly variation of

the stages of the life-cycle is given in detail in the following table which shows the seasonal sequence of generations through the year. Theoretically, there is an annual series of 10 complete generations at the average rate of development.

Theoretical sequence of generations of Hapalia machaeralis in an average year at Dehra Dun, U. P., India.

Days from January 1.	Month	Incubation	Larval period	Pupal period	Pre-oviposition	Generation	Total life cycle	Days from January 1
31	January	Larva hibernates				10		31
59	February		,,			10		59
90	March		,,	15	5	10		90
120	April	4	14	7	3	1	28	118
		4	12	6	3	2	25	143
151	May	3	12-13	5	3	3	23	166
181	June	3	12	6	3	4	24	190
212	July	3	12-14	5	4	5	25	215
243	August	3	13	5	3	6	24	239
		3	13	6	3	7	25	264
273	September	3	13	6	3	8	25	289
304	October	3	14	7	4	9	28	307
334	November		Larva hibernates			10		
365	December			,,		10		

NOTE: The sequence of generations is assumed to start with moths derived from hibernating larvae towards the end of March and which oviposit on the 1st of April. There are in all 10 generations; under favourable circumstances the last generation can be completed in about 150 days, incubation-period 5 days, larval 125, pupal 15, and pre-oviposition 5 days.

BURMA

The ecology of *Hapalia machaeralis* in Burma was studied at the Forest Entomologist's insectary in Pyinmana.

Egg: The individual period of incubation varies throughout the year from 2 days in May, June to 6 days in December,

January, the monthly mode being 3 days from February to November. Eggs can be kept unhatched for several days in artificial temperatures of 45°–50°F.

L a r v a : The individual period varies from 11 to 21 days; the monthly mode varies from 19 days in December, January to 11 in May, the prevailing mode for summer and monsoon being 13 days (see table, page 680). The length of each of the 5 larval instars and of the prepupal stage is very uniform, a minimum of 2 days and a maximum of 3 or 4 days in each case.

P u p a : The pupal period varies from 4 to 11 days, the monthly mode reaching its minimum at 4 days in May and its maximum at 10 days in January and being about 6 days for half the year.

M o t h : The maximum life recorded for the moth at Pyinmana is 26 days (unmated female) and 30 days (unmated male); mated individuals do not live so long, the average longevity being about 9 days in June–August and about 16 days in the coldest months December–March.

P r e - o v i p o s i t i o n and o v i p o s i t i o n : The pre-oviposition period of the female varies individually from 1 to 8 days and the mode is 3 or 4 days between March and October. The oviposition-period extends up to 17 days and lasts about a week on the average during which time over 200 eggs may be laid.

L i f e - c y c l e : The life-cycle from egg to emergence of the moth varies from 17–38 days (individual minimum and maximum), and from 18 in May to 34 in January (monthly modes). The total life-cycle from egg to egg, i.e., including the pre-oviposition period, varies from 18–46 days (individuals) and from 21–40 days (monthly modes). Monthly variation of the stages of the life-cycle is given in detail in the following table which shows the seasonal sequence of generations through the year. Theoretically, a series of thirteen full generations is possible in one year. At the Pyinmana insectary *H. machaeralis* has been bred continuously for 60 generations at the rate of 13 per annum. There is no indication that it hibernates in any part of Burma and larvae may be found on teak throughout the year. Compared with the data for south India in the table on page 676 the rate of development in Burma is throughout slower except in May when a generation is completed very quickly.

Theoretical sequence of generations of Hapalia machaeralis on Tectona grandis in an average year at Pyinmana, Burma.

Days from January 1.	Month	Incubation	Larval period	Pupal period	Pre-oviposition	Generation	Total life-cycle	Days from January 1.
31	January	5	19	10	6	1	40	40
59	February	3	16	8	5	2	32	72
90	March	3	13	6	4	3	26	98
120	April	3	12	4-5	3	4	23	121
151	May	3	11	4	3	5	21	142
181	June	3	13	5	3	6	24	166
212	July	3	12-13	6	3	7	24	190
243	August	3	13-14	6	3	8	25	215
273	September	3	13-14	6	4	9	26	241
						10	26	267
304	October	3	13-14	6	4	11	27	294
334	November	3	15	6-8	5	12	29	323
365	December	5	19	7-10	6	13	39	362

NOTE: The sequence of generations is assumed to start with moths emerging on the 1st January and to continue without interruption during the leafless period (on adventitious foliage). Thirteen full generations are possible at the average rate of development in an average year.

Food-preference

Alternative food-plants: In India *machaeralis* breeds on *Callicarpa arborea* and *C. macrophylla* and will also feed on *Tectona hamiltoniana*. These food-plants are not commonly utilised except where the trees occur in abundance. The rate of development on *Callicarpa* is much slower than on teak.

In Java it feeds on *Callicarpa cana*. Kalshoven, 1934, records that during a special investigation of the insects of economic importance in Javanese teak forests, *machaeralis* was never bred from teak, nor did any evidence present itself of its possible occurence on teak in West and Middle Java; the concludes that teak is not the natural food-plant of *machaeralis* in Java and it

is a matter for speculation what is the reason for this divergence in habits of the species in India and Java.

Quality of the food-supply: Moths lay eggs on all kinds of teak foliage from the young reddish or soft flaccid green leaf to the old rough dark green or even brown discoloured leaf. The newly hatched larvae are actively mobile and, when given the choice, they will select the youngest, softest leaves and avoid the mature tough kind. Nevertheless a *machaeralis* larva can survive on an exclusive diet of tough brittle leaf throughout life, but the rate of growth is slower and the percentage of mortality is higher than on soft light green leaf; the pupal period of larvae fed on tough leaf is also increased. This difference with food-requirements of *machaeralis* and *puera* explains the abundance of the former at the end of the growing-season when *puera* is absent.

Under certain conditions the terminal buds of the leader and lateral shoots of teak are gnawed or hollowed out, usually after complete stripping of the leaves; forking results from the death of a terminal bud.

Incidence of defoliation

Seasonal abundance: The seasons at which *H. machaeralis* is likely to be conspicuously abundant or epidemic in pure teak crops are determined primarily by the climate of the locality (as for *puera*, page 615).

In south India at Nilambur *machaeralis* may be abundant in April, May and in November; during the monsoon and the dry hot months preceding it the defoliator is not usually abundant. In Coorg it is scarce during the monsoon and is likely to be most abundant during the period October–January. In Bombay it is most abundant during the hot dry period (May, early June) preceding the monsoon and again from September. In central India exceptionally early and ample monsoon rainfall may produce an epidemic of *machaeralis* in May, June; otherwise the period of greatest abundance is from September onwards. At Dehra Dun *machaeralis* is extremely rare in June–August; it may be abundant in October, November. In Burma there is a higher average abundance during the monsoon-season which may reach a maximum in October–December.

After light to moderately heavy skeletonisation the leaves do not invariably fall but may remain throughout the growing-season or to the normal date of leaf-fall. This persistence of the evidence of an attack by *machaeralis* may create a false impression of its prevalence and of the period at which it is actively feeding.

Crop-age: The data recorded for *Hyblaea puera* on pages 616, 617, apply also to *H. machaeralis*.

Economic importance

The economic importance of teak defoliators is discussed on

pages 617–619. The epidemics of *machaeralis* which occur at the end of the growing-season and destroy the foliage during the period autumn-spring probably have very little effect on the current increment of that year; diameter-growth of teak stops by November in most localities in India. On the other hand the increment and height-growth of the following year may be affected if food-reserves are destroyed and buds are killed; precise measurements have not been made of these factors.

LITERATURE:

(see literature on Hyblaea puera, page 617 and teak Defoliators, page 619).

Dawkins C. G. E., 1921, *Ind. For.*, XLVII, pp. 209-213, Notes on an attack of P. machaeralis on teak in Zigon and Tharrawaddy divisions in 1920.

Kalshoven L. G. E., 1934, *Tectona*, XXVII, pp. 70-75, De voedsterplant von Pyrausta machaeralis Walk. op Java.

Stebbing E. P., 1903, *Dept. Notes*, II, pp. 301-311, pls. xviii, xix, Pyrausta machaeralis.

— 1908, *For. Zool. leaflet*, No. 3, The teak leaf skeletoniser.

Hapalia ochrealis defoliates *Gmelina arborea* and *Premna latifolia*.

Hemiscopis suffusalis defoliates *Dipterocarpus tuberculatus* and *Glochidion coccineum*.

Hypargyria metalliferella defoliates *Celastrus paniculata*; the pupal period is about one week in July.

Hypsipyla robusta, The Cedar, Toon or Mahogany Shoot-borer.

This borer is a serious pest in plantations of cedars and mahoganies in subtropical and tropical forests of the Indo-Malayan Region, Australia, Africa, West Indies and South America. In the American region it is replaced by the form, *H. grandella*. The recorded food-plants are *Carapa guianensis*, *C. moluccensis*, *Cedrela australis*, *C. mexicana*, *C. multijuga*, *C. odorata*, *C. serrata*, *C. sureni*, *Chickrassia tabularis*, *Entandophragma angolense*, *E. utile*, *Khaya anthotheca*, *Soymida febrifuga*, *Swietenia candollei*, *S. macrophylla*, *S. mahagoni*. In species with small fruits such as *Carapa* and *Cedrela* it attacks the fruits also; in other genera it is primarily a shoot-borer.

Moth: [fig. 157, No. 7; fig. 181, Nos. 7, 8]. Pale rufous-brown mixed with grey and black; forewing with veins streaked with black and crossed with zigzag black lines and patches; hindwing whitish, semi-hyaline, the margin and costal zone darker; wing-expanse 26–32 mm. male, 28–42 mm. female. Larva: [fig. 156, No. 17; fig. 181, Nos. 2–5]. The colour varies from pale straw through brown, pink, green to blue with a series of black setiferous spots in 5 longitudinal rows on each side of the body, the spots of the 1st and 3rd rows being larger. In the 4th instar the newly moulted larva is reddish-brown which gradually fades to pinkish, purple or reddish-blue and finally to light blue, which colour is characteristic of the mature larva.

Length 19-29 mm. Pupa: [fig. 181, No. 6] brown, 10·5-15·7 mm. Egg: white, oval, 0·9×0·75 mm. For technical descriptions see Beeson, 1919.

Life-history

The life-history and the sequence of generations of *H. robusta* vary with the food plant and the climate of the region. In temperate and subtropical regions there are fewer generations and the parts of the tree attacked differ in some of the generations; in the tropics the more numerous generations feed almost entirely in the shoots of the food-plants.

NORTH INDIA AND BURMA

As a pest of *Cedrela toona* in north India and upper Burma it is known as the Toon Fruit and Shoot-borer; there are 5 generations a year. (see the diagram of the seasonal history in Part Two, section on Life-cycles).

1. The flower generation: The eggs of the first generation are laid on the flowering shoots of *Cedrela toona*, early in March. One female lays 400–600 eggs. The larvae feed gregariously on all parts of the paniculate inflorescence, binding together individual flowers or adjacent groups of flowers with a loose network of silk threads in which portions of the petals, ovaries, pedicels, etc. and fragments of larval excrement are entangled [fig. 181, No. 9]. A panicle in which a colony of larvae has fed remains a ragged mass of shrivelled floral fragments long after the dispersal of the larvae. Although the network of silk provides ample protection for the growing caterpillars, each individual before moulting prepares a cell of more densely woven silk in which to shed its skin. The life-cycle lasts 24–29 days (egg 4–5, larval stages 4+2+2+4, pupa 8–12 days); the earliest moths appear in the 4th week of March; the limits of the generation lie between 8 and 9 weeks.

2. The fruit generation: By the time the 2nd generation larvae are abundant the flowers of toon are falling and the young fruit capsules are developing. The larvae feed on the fruits selecting the youngest and softest while in the 1st instar and feeding mainly on the epidermis. Older larvae attack more advanced fruits and feed within them, eating the seeds and the soft white tissue of the dissepiments and the axis, avoiding the harder epidermis of the valves. Larvae of the 1st instar are rarely able to penetrate the outer epidermis of the fruit-capsule, if it is at all suberised, and in the absence of softer green fruits are unable to survive. During the feeding-period the fruits are bound together in groups of 3 to 5 with silk-web, in which are entangled brown desiccated bits of fruits and pellets of excrement [fig. 181, No. 16]. A larva lives inside one fruit until the edible portions are consumed, after which it emerges and bores a hole into the fruit immediately alongside, fastening the new fruit to the one

previously occupied with silk threads, While feeding within a fruit it plugs the entrance-hole by a compact mass of excreta and ejected pieces of pith [fig. 181, No. 11]. The life-cycle lasts 24-29 days (egg 4-5, larval stages 4+2+2+4, pupa 8-12 days); the earliest moths appear in the 3rd or 4th week of April from eggs laid in the 4th week of March; the limits of the generation lie between 9 and 10 weeks.

Pupation of 1st and 2nd generations: Larvae of the 1st and 2nd generations when full-grown, lower themselves from the crown of the tree in the early morning by means of silk threads. Many, checked in their descent by the lower branches, abandon the thread and crawl down the trunk. Others reaching the ground direct often crawl up the trunk again in search of crevices or recesses in the flakes of bark suitable for pupation. During their wandering silk is continuously spun in the paths of individual larvae, and on badly infested trees with smooth bark the quantity of silk spun is enough to make a sheet of silk-web round the whole trunk of the tree from the crown to the ground. In a suitable sheltered place the larvae pupate in cocoons of loose white silk. Cocoons are often closely packed in masses 2 and 3 layers deep amounting to more than 1,000 to the square foot.

3, 4 and 5. The shoot generations: Larvae of the 3rd, 4th and 5th generations feed as borers in the soft shoots of the current year. Eggs are laid on the new unexpanded leaves [fig. 181, No. 1]. The larva on hatching descends to the stouter part of the growing shoot and feeds by removing the epidermis in irregular patches, at the same time testing the shoot for a suitable spot to enter. If too vigorous tissue is selected as the site of entry, the attack fails and a flow of sap or gum drowns or entraps the larva; constant tapping of the sap weakens the shoot and the

Fig. 181. Seasonal history of Hypsipyla robusta.

No. 1—Young leafy shoot of *Cedrela toona* with egg of *Hypsipyla robusta.* Nos. 2-5—1st, 2nd, 3rd and 4th stage larva respectively. No. 6—Pupa. Nos 7 and 8,—male and female moths. No. 9—Inflorescence of *C. toona* with *robusta* larvae feeding on flowers, showing webbed mass of flower-fragments and excreta. No. 10—Panicle of immature fruits of *C. toona* with larvae feeding on and in the fruits, showing frass and emergence-holes (half natural size). No. 11—Fruit opened out to show larva within. Fig. 12—Current year's shoot of *C. toona* attacked near summit by a *robusta* larva showing No. 13—the excrement and particles of pith ejected. No. 14—Current year's shoot towards end of the growing-season, opened out to show larva within and silk-work spun previously to hibernation. No. 15—Last year's shoot, dead and broken as a result of attack by *H. robusta.* No. 16—Moth in resting attitude.

All figures except No. 10 are natural size.


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larva eventually gains an entrance. Once established within the shoot it excavates a central tunnel in the pith and increases it gradually until it may be 2 feet long. A larva usually remains in one shoot throughout its life but, in the later instars, may abandon a stunted shoot and attack a second, boring in where the epidermis is more suberised or at the axil of a leaf or smaller twig. A gummy mass of frass bound with silk marks the entrance-hole [fig. 181, No. 13]. The shoot above the entrance-hole dies or shrivels, eventually falling over or breaking off. Below the site of entry the shoot with its buds and lateral shoots dies and dries up as far downwards as the tunnel extends [fig. 181, No. 15].

Pupation of the 3rd, 4th and 5th generations: Within the shoot-tunnel the larva constructs at intervals partitions of silk [fig. 181, No. 14] which act as a safeguard against the entrance of predators and parasites and rain-water. Pupation occurs in a cocoon towards the base of the tunnel after making at least one partition of silk. Fifth generation larvae which hibernate without pupation invariably construct silken hibernacula.

The 3rd generation has a life-cycle of 66–78 days (egg 4–5, larval stages i 7–9, ii 7–10, iii 14–16, iv 21–24, pupa 13–14 days). The limits of the generation lie between 17 and 19 weeks.

The life-cycle of the 4th generation lasts 64–79 days, the periods being similar to those of the 3rd.

The 5th or overwintering generation has a life-cycle of 147–170 days (egg 4–5, larval stages, i 7–9, ii 8–9, iii 14–15, iv 101–117, pupa 13–15 days). The limits of the generation lie between 28 and 31 weeks with the 4th stage larva passing most of its time in a hibernaculum in the tunnel. The generation begins in October when the autumn flush of shoots occurs, and most of the larvae have bored into shoots before winter leaf-shedding begins.

SOUTH INDIA AND CEYLON

In south India *H. robusta* occurs from low levels upto 3,000 feet, as a borer of shoots. It does not attack the fruits of mahoganies and does not breed commonly in the flowers and fruits of large trees of *Cedrela* but occasionally resorts to fruits of *Carapa*. It is able to complete a series of generations throughout the year in shoots. The variation in length of the life-cycle has not been accurately determined; at a quick rate of development it may take 7 or 8 weeks with a pupal period of 10 days. Larvae are found in shoots and moths emerge throughout the year and are most abundant in August–December. Several shoots may be bored by one larva. In Ceylon the shoot-borer is abundant in plantations of *Cedrela* and *Swietenia* except at the higher altitudes, above 5,000 feet.

Fig. 182. Hypsipyla robusta attack on Cedrela toona.

Arrows mark the sites of attack of 3rd and 4th generation larvae on the current year's shoots.

JAVA

In Java the development of *H. robusta* in mahogany is quicker than in the shoot-boring generations in toon in north India. The life-cycle is completed in 4-7 weeks. The longitudinal growth of mahogany saplings is periodic and full-grown top-shoots end in a bud which does not sprout before the youngest part has become lignified. During this period the top-shoot becomes more and more unsuitable for the borer. Ordinarily the larva matures only in a robust shoot which is still sprouting at the tip or is full-grown. Many larvae leave the original tunnel because it is too short or too lignified for full growth. The small-leafed mahogany forms more short shoots than *S. macrophylla* of the same age and consequently the tops of *S. mahagoni* are more often susceptible to attack but this circumstance is more or less counterbalanced by the fact that the lateral shoots of *mahagoni* are too small to feed one larva to maturity (Kalshoven).

Economic importance

As a fruit or seed pest *H. robusta* is capable of destroying the greater part of the seed-crop of *Cedrela toona* and *Carapa moluccensis* in India; and similar damage is caused to other species of trees in Australia and the West Indies.

As a shoot-borer of young trees of *Cedrela* and *Swietenia* it attacks seedlings of vigorous growth when they are as young as 3 months and less than 1 foot high; in plantations a 100 percent infestation may be reached in the 2nd year; later on the liability of the sapling or pole depends not so much on its age as on the density of stocking and on its rate of growth and the less frequent production of soft green shoots; older trees in which height-growth has ceased are less liable to serious attack because the production and elongation of the terminal shoots is seasonally restricted and the borer cannot breed continuously in older stands.

The combined work of the shoot-boring generations on young cedar and mahogany trees may completely nullify the season's growth; not only are the leaders of the current year killed but also the laterals which have made progress on the woody stems of the previous years. The growth of a sapling appears to be completely checked but, in the course of time, occasional shoots escape the borer and become lignified so that some upward progress is made. Frequent bifurcation produces a dense bushy plant. Fig. 182 shows young saplings of *Cedrela toona* in which the leader and its substitutes have been repeatedly killed back.

Retardation of growth in the early years of a plantation is serious but the chief economic damage is the formation of forked, crooked and branchy boles which reduce the outturn of better class logs. The poor condition of pure plantations of toon in India has often caused them to be written off at a loss of Rs. 15 to 30 per acre and interest in the species to be abandoned. The chief factor militating against the formation of successful planta-

tions of mahogany was for many years the shoot-borer. Foresters in other continents have also experienced failure with their indigenous mahoganies. Nevertheless, abandoned plantations have struggled through and have from time to time revived interest in these meliaceous timbers. In natural regeneration, on the other hand, the incidence is very low or negligible under the shade of mother-trees. It is now recognised that overhead and lateral shade considerably reduce the incidence of the pest and that a tolerable amount of shade is compatible with a reasonable rate of growth in favorable climates. The silvicultural measures which can effectively control the borer are discussed in Part Two.

LITERATURE:
Beeson, 1919, ***Ind. For. Rec.***, VII, vii, figs., pls., The life-history of the toon shoot and fruit borer with suggestions for its control
Kalshoven L. G. E., 1926, ***Meded. v. h. Inst. v. Plantenziekten***, No. 69, Beschadigingen, ziekten en plagen van mahonie aangeplant op Java.
Laurie M. V., 1936, ***Mahogany and its future possibilities in Madras.***

Ilythia trisquamella defoliates *Xylia dolabriformis.*

Isocentrus illectalis feeds on *Abrus precatorius.*

Jocara malefica defoliates *Bauhinia racemosa, Grewia tiliaefolia, Lagerstroemia flos-reginae, L. lanceolata, Saccopetalum tomentosum* and *Terminalia tomentosa* between April and August; pupal period 11 days in July in a cell in the soil lined with silk.

Lamida carbonifera defoliates *Anogeissus latifolia, Diospyros melanoxylon, Lagerstroemia parviflora, Garuga pinnata, Mangifera indica, Terminalia belerica, T. paniculata* and *T. tomentosa* in April to October. The leaves are matted together with a loose silk web in the shelter of which the larvae feed, skeletonising and eating irregular patches. The pupal period, passed in an earthen cell lined with silk, is about 9 to 13 days in the monsoon season. **L. moncusalis** is one of the species defoliating *Shorea robusta* in June, webbing together the leaves and young shoots. Pupation occurs in July and moths in July–August. It also feeds on *Lagerstroemia flos-reginae* and *Mangifera indica.* **L. nubilalis** defoliates *Bursera serrata* and *Garuga pinnata.*

Lamoria adaptella bores the seeds of *Shorea robusta* emerging in July, August; the larva is shown in fig. 156, No. 8.

Lamprosema diemenalis defoliates *Derris elliptica, Desmodium cephalotes, Flemingia chappar, F. paniculata* and *Ougeinia dalbergioides.* The pupal period of the cold weather brood varies from 2 to 4 weeks (March and February). It is also a leaf-roller of pulses, soybeans, etc. Widely distributed in Asia and Australia.

Laodamia strigivenata defoliates *Bauhinia racemosa.*

Leucinodes orbonalis, a minor pest of brinjal, widely distributed, also feeds on the foliage and fruits of *Solanum xanthocarpum.*

Locastra muscosalis defoliates *Lannea grandis,* rolling the leaves. The reddish-yellow caterpillar pupates in a tough

flattened brown cocoon along the edges of which are numerous pores; there is an inner cocoon of yellow silk, loosely woven. The pupal period is 3 or 4 weeks in August.

Lygropia obrinusalis is a defoliator and leaf-roller of *Callicarpa arborea*, *Grewia asiatica*, *G. hainesiana*, *G. tiliaefolia*, *G. vestita*, *Helicteres isora*, *Wrightia tinctoria*. The larvae feed inside a rolled up leaf eating the tissues of the inner layer, abandon it and roll up a fresh leaf; 8–10 young larvae live in a single leaf-fold. The insect is active from March to November in several generations; the pupal period lasts from 6 to 10 days. The caterpillar has a high average parasitism-percentage which rises to 65 percent maximum; the parasite-complex comprises at least 23 species of Chalcididae, Braconidae and Tachinidae of which 5 are primary parasites of *Hapalia machaeralis* and *Hyblaea puera*, the teak defoliators. As it feeds on several species of *Grewia* and *Helicteres isora* which are associated with teak in mixed forest or in undergrowth it is an important and desirable species in the biocoenosis of teak plantations, and its presence as well as that of *Lygropia quaternalis* can be assured by protection of its foodplants (see section on Biological Control, teak defoliators).

Lygropia quaternalis, closely allied to *L. obrinusalis*, is also a leaf-roller of *Grewia asiatica*, *G. dissperma*, *G. humilis*, *G. laevigata*, *G. tiliaefolia*, *G. vestita*, *Helicteres isora*. The leaf is rolled up from apex to base or from the side and only the chief veins remain uneaten. In habits and seasonal history it is similar to *L. obrinusalis*. The caterpillar has a high average parasitism-percentage rising to about 50 percent and due to a parasite complex of 27 species of which 9 species are primary parasites of *Hapalia machaeralis* or *Hyblaea puera*. It is therefore like *obrinusalis* highly desirable in the teak plantation biocoenosis. (See section on Biological Control, teak defoliators).

Beeson and Chatterjee, S. N., 1939, *Ind. For. Rec.*, Ent., v, No. 5, pp. 363-365.

Macalla plicatalis feeds on *Tectona grandis*.

Margaronia actorionalis feeds on *Artocarpus integrifolia*.

Margaronia caesalis. The larva is a borer of the shoots of young *Artocarpus chaplasha*, *A. elastica*, *A. integrifolia*, and *A. rigida*. The youngest stages of the larva bore in the unfolded leaves and buds mining the midrib; later they penetrate into the pith of the shoot making a tunnel several inches long where pupation takes place. Plants growing under shade or with herbaceous weeds are less subject to attack. **M. glauculalis** defoliates *Holarrhena antidysenterica*, *Tabernaemontana heyneana* and *Wrightia tinctoria*. **M. hilaralis** defoliates *Anthocephalus cadamba* and *Duabanga sonneratioides*. The larva is grey with numerous black spots. The leaf is skeletonised from below and a portion is folded over for a shelter; there may be several folds on a large

leaf. A young leaf of about 4 inches is folded along the midrib and the edges are neatly stuck together. The pupal period is 6–8 days in September.

Margaronia laticostalis. The larvae are gregarious resting during the day under tents of silk and frass spun on the foliage so that the leaves are joined together. When the colony is disturbed the heads are struck against the leaves, producing a rattling noise. The mature larva is dark amber-brown with lateral bands of black tubercles each bearing one or two white hairs; length 1–1½ inches. The pupa is light brown with black spots. The moth [fig. 156, No. 19] is pure white with a golden yellow edge to the forewing. A generation occurs in September with moths in October after a pupal period of 10 days; another generation occurs in December with moths in January after a pupal period of 12–14 days. Other generations occur between May and September producing moths in all months. The species is a widespread defoliator of *Holarrhena antidysenterica.* It is an alternative host of 2 species of parasites attacking teak defoliators.

Margaronia marginata feeds on *Alstonia scholaris, Bombax malabaricum.* **M. pomonalis** feeds on young foliage of *Glycosmis pentaphylla, Holarrhena antidysenterica, Tabernaemontana heyneana, Sterculia urens, Wrightia tinctoria.* **M. punctiferalis** feeds on *Sarcocephalus cordatus* skeletonising the leaves.

Margaronia pyolalis. This species is a widespread defoliator of mulberries, *Morus indica* and *M. alba.* The full-grown larva is bluish-green and nearly an inch in length. Feeding takes place between the leaves which are closely webbed together. At first only the surface-tissue of the leaf is eaten but the mature larva consumes the whole leaf except the larger veins and midrib. When outside the leaf-shelter the larvae are very active and spin considerable quantitites of silk. Pupation occurs in a cocoon between the leaves. The pupal period is 4 to 8 days in September and 6 to 11 days in October. Hibernation occurs during the cold weather from mid December to February.

Margaronia stolalis feeds on *Ficus glomerata.* **M. vertumnalis** feeds on *Alstonia scholaris, Bombax malabaricum, Jasminum pubescens, Tabernaemontana coronaria,* binding two leaves together by the edges and eating from inside. It also feeds on *Tectona grandis.* The larva is dark green with a reddish head and numerous black markings on thorax and abdomen; length 32 mm. Larvae occurring early in the monsoon produce moths at the end of July. Larvae living in November hibernate and pupate in the middle of March producing moths at the end of March to mid-April.

Maruca testulalis feeds on the foliage of *Casuarina equisetifolia, Derris elliptica* and *Xylia dolabriformis*; it is also a pod-borer attacking cultivated Leguminosae. In Burma it defoliates forests of *Xylia dolabriformis* in association with *Striglina*

scitaria (Thyrididae), and is abundant in July–November.

Massepha absolutalis defoliates *Dendrocalamus strictus* in the early part of the rains The pupal period is 5 to 8 days in August to October. Hibernation occurs as a larva inside the leaf case.

Mecyna gilvata defoliates *Indigofera pulchella, Sophora griffithi* and *S. tomentosa* at the end of the rains. The larva is 1¼ inches long, light green with black and yellow lateral lines. Pupation occurs in a large cocoon of white silk. After a prepupal period of two weeks it passes the winter as a pupa and moths emerge in February–March.

Myelois atelogramma defoliates *Miliusa velutina, Saccopetalum tomentosum, Urena lobata;* the pupal period is about 25 days in February falling to 15 days in March from caterpillars feeding through the cold season. Other generations occur in June July.

Nephopteryx rhodobasalis feeds on *Cassia fistula.* The caterpillar webs two or three leaves together and feeds between them on the interveinous tissue. The larval period is variable and may extend to 10 weeks; the pupal period is 50 days in January, 23 days in February, 16 days in March, 7–10 days in July, August. **N. fessalis** feeds on *Anogeissus latifolia* in June–July; it frequently pupates in the cracks of the bark of other trees. **N moringae** defoliates *Moringa pterygosperma* by feeding on the young buds. The life-history is described by M. C. Cherian and M. Basheer, 1939, *Ind. Jl. Ent.*, I, pp. 77–81, pl. II.

Orthaga aenescens defoliates *Litsaea sebifera.* **O. mangiferae** defoliates *Mangifera indica*, feeding gregariously on the young leaves which are webbed together.

See Misra, C. S., 1932, *Ind. Journ. Agr. Sci.*, II, pp. 539–548, pls. lviii, lix.

Pachyzancla stultalis defoliates *Achyranthes aspera, Boerhaevia diffusa, Plectranthus incanus*; the pupal period lasts about a week in September.

Pagyda botydalis occurs from India to New Guinea and defoliates *Premna latifolia* and *Callicarpa arborea* in Burma.

Pagyda salvalis is widespread in Asia. The small caterpillar feeds on the flowering shoots of *Tectona grandis.* Pupation occurs in a cocoon in the dried infloresence or in the soil or in bark cracks. It also damages stored teak seeds.

Phlyctaenia flavofimbriata defoliates *Dendrocalamus strictus* during the monsoon; the pupal period is 8 days.

Pilocrocis milvinalis (=barcalis) fastens together the leaves of *Cassia fistula* and feeds on the inner layers. It also feeds on *Randia uliginosa.* There are several generations with a pupal period of 10 days in May to 27 days in November. It is an al-

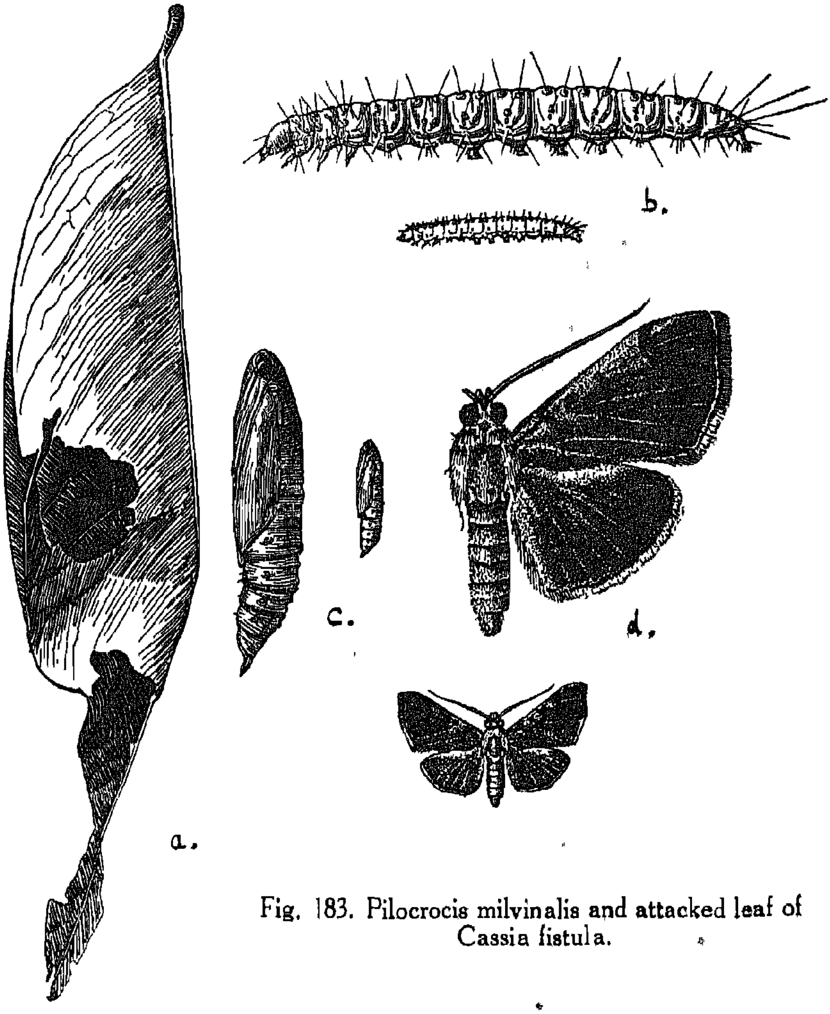

Fig. 183. Pilocrocis milvinalis and attacked leaf of Cassia fistula.

ternative host of 4 species of parasites of the teak defoliators. [fig. 183].

Prasinoxena monospila. The moth flies in April–June and lays eggs on the bark of young living trees of *Amoora wallichii.* The caterpillars feed gregariously on the bark, eating out patches of several inches in diameter or bands running spirally round the bole and main branches. The living bark and cambial region are destroyed, and if the damage is extensive enough to girdle the stem the foliage withers and the tree dies. In February, March the larvae pupate in silken cocoons which are formed in clusters in the excavated areas under a cover of silk and debris.

Prorodes mimica defoliates *Laportea crenulata.*

Psara bipunctalis feeds on *Solanum torvum.*

Psara see **Pachyzancla.**

Pycnarmon cribrata, widespread in Asia and Africa, defoliates *Vitex negundo.* The life-cycle is short with a pupal period of 4–8 days in April–October. **P. lactiferalis** feeds on *Vitex canescens.* **P. meritalis** feeds on *Blumea balsamifera* and *Chickrassia velutina.*

Pygospila tyres defoliates *Holarrhena antidysenterica, Tabernaemontana heyneana* and *Wrightia tinctoria.* The caterpillar is creamy with round black spots.

Pyralis manihotalis breeds in decaying *Opuntia monacantha.* **P. pictalis** breeds in bored bamboos and is a borer of the shoots of *Millettia auriculata, Phoebe lanceolata* and *Populus alba.*

Pyrausta bambucivora and **P. coclesalis** are leaf-rollers of bamboos, *Cephalostachyum pergracile, Dendrocalamus strictus.* The former is injurious in bamboo forests in the Punjab particularly in moist nullahs during July–October. Eggs are deposited in masses of 6 to 40 and the larva feeds between the rolled up leaves and pupates in a cocoon made inside a roll.

Pyrausta celatalis defoliates *Callicarpa arborea, C. lanata, C. macrophylla* and *Rhynchosia cyanosperma* **P. diniasalis** feeds on the young leaves and terminal buds of *Populus ciliata* and *Salix pentandra.* **P. straminea** feeds on *Tectona grandis*, rolling tough hard leaves.

Salebria hemictenis feeds on *Casearia graveolens* and *Elaeodendron glaucum.* **S. morosalis** feeds on *Desmodium gangeticum, Jatropha curcas, Flemingia* sp. and *Uraria lagopoides*; the pupal period is 7 to 9 days in June to August. **S. paurosema** feeds on *Cassia fistula* also eating the flowers in June.

Salebria strigivenata see **Laodamia.**

Sameodes cancellalis occasionally feeds on *Tectona grandis.*

Sylepta aurantiacalis feeds on *Buchanania latifolia* and *Shorea robusta.*

Sylepta balteata is a widespread species in Europe, Asia, and Africa. In India it feeds on *Boehmeria malabarica, B. platyphylla, Bursera serrata, Garuga pinnata, Grewia tiliaefolia, Lannea grandis, Pterospermum semisagittatum, Rhynchosia cyanosperma, Shorea robusta.* The leaves of small-leafed species are usually rolled or spun up by the caterpillar. It is subject to heavy parasitism by at least 13 species of Tachinidae, Braconidae, etc. including 8 species that are primary parasites of either *Hapalia machaeralis* or *Hyblaea puera*, the teak defoliators. As it feeds on several species of trees asssociated with teak in mixed forest or in undergrowth it is an important and desirable species in the life-community of the teak defoliators and its presence can be assured by protection of its food-plants. It is active from March to November.

Sylepta costalis defoliates *Phoebe hainesiana.* **S. crotonalis** occurs from Ceylon to Formosa and Borneo. It defoliates *Leea*

aequata, *L. crispa* and *L. sambucina* and *Melastoma malabathricum*, from May to November and is attacked by 12 species of parasites of which 3 species are primary parasites of teak defoliators.

Sylepta derogata, The Cotton Leaf-roller, a species widespread in Asia, Africa, Oceania. Eggs are laid singly on the lower surface of leaves of cotton. The larva rolls up portions of the leaf into a tight conical or cylindrical roll fastened with silk threads, and feeds on the portions of the leaf outside. The mature larva (one inch long) has a smooth body of transparent grayish or greenish colour and a brown head. There are 6 moults. Pupation takes place in the roll without the formation of a cocoon, or in the soil, or among dead leaves. The moth is pale yellow marked with a network of dark lines; expanse 1¼ inch. The length of the life-cycle is 4 weeks (egg 2–3 days; larva 13–18 days; pupa 6–9 days) during the warmer parts of the year. In October and November the mature larvae find sheltered places in leaf-debris or in bark, and pass the winter in flimsy cocoons. Pupation and moth-emergence begins from March onwards.

This species is a serious pest of cotton in India. It also feeds on *Abutilon indicum*, bamboo, *Hymenodictyon excelsum*, *Kydia calycina*, *Pterospermum* sp., *Sida cordifolia*, *Sterculia villosa*, *Thespesia lampas*, *T. populnea* and on various species of Malvaceae (*Althaea*, *Hibiscus*, *Urena*) and other cultivated crops.

Lefroy H. M., 1908, *Mem. Dept. Agr. Ind.*, II, 6, The cotton leaf roller.
Ramakrishna Ayyar T. V., 1932, *Agr. Dept. Madras*, Bull. 28, p. 12, pl. III.
— 1933, *Agr. Dept. Madras*, Bull 34, p. 12, fig. 7.
Husain M. A , 1934, *Punjab Agr. Dept.*, Seasonal Notes, XII, 2. pp, 48, 49. The cotton leaf-roller and its control.

Sylepta lunalis occurs throughout India and feeds on *Helicteres isora*, *Lantana aculeata*, *Leea aspera*, *Leea crispa*, *Melastoma crinita*, *Quercus incana* and *Vitis vinifera* during the rainy season June–October; the pupal period is 8 to 10 days. The moth is dark grey with a light streak near the margin of the forewing; expanse about one inch. The larva is three quarters of an inch long with tufts of white hairs; it feeds gregariously and carries the skins of previous moults on the thorax behind the head. **S. sabinalis** defoliates *Girardinia heterophylla*, *Urtica parviflora*. **S. scinisalis** defoliates *Litsaea polyantha* and *Sarcosperma arboreum*. **S. straminea** feeds on *Tectona grandis*, the larva rolling a part of the leaf; the pupal period is 10 days in September.

Terastia egialealis bores the living branches of *Erythrina arborescens*, *E. lithosperma*, *E. suberosa* and *E.* spp.

Trachylepidea fructicassiella. The larva, 25–30, mm., bores the pods of *Cassia fistula*; the moths emerge in March–May. It is a regular pest of the fallen pods and prevents the development of an export trade in this commodity.

Tyspanodes linealis defoliates *Bombax malabaricum*.

PTEROPHORIDAE

(misplaced from page 669)

PLUME MOTHS are usually classed with the Microlepidoptera or alternatively in the Pyraloidea.

Fletcher T. B., 1921, *Mem. Dept. Agr. Ind.*, Ent. VI, pp. 1-31, pls. I-VII, Pterophoridae.
— 1931, *Catalogue Ind. Ins.*, Part 20, Alucitidae.
— 1932, *Imp. Counc Agr. Res., Sci. Mon.*, No. 2, pp. 1-13, pls. I-VIII, Alucitidae (Pterophoridae).

Cosmoclostis premnicola feeds as a larva on the upper sides of leaves of *Premna latifolia*, or eats holes through both surfaces. Pupation occurs on the leaf.

Oxyptilus causodes feeds as a larva inside the fruits of *Dillenia indica* and *D. retusa*. The larva, when full-fed and about 13 mm. long, leaves the fruit and suspends itself nearby for pupation. Moths appear in January to March (in Dehra Dun).

Platyptilia pusillidactyla. The Lantana Plume Moth.

A dark brownish plume moth, the forewings speckled with lighter tones (expanse ½ inch), which lays its eggs on the unopen flower-buds or clusters of opened flowers of *Lantana aculeata*. The larva hatches in 4–6 days and bores into the rachis or base of the corolla tube feeding first on the ovary and anthers; the adjacent bud or flower or young fruit is similarly attacked. One caterpillar may eat 15–20 flowers before becoming full-grown, when it is about 6 mm. long and bright yellow in colour. A cocoon is prepared in a cavity gnawed in the fruit-receptacle and disguised with dried particles of flowers or fruits. The yellow-brown pupa has spines on the back of the hindermost abdominal segments and by means of these can emerge halfway from the cocoon to allow the moth to escape. At Dehra Dun the life-cycle lasts 15–18 days during March–May, 14 days in August and September and 18–54 days during the colder season October–December. It hibernates as a pupa from part of December to February and moths appear in March.

Economic importance: The insect attacks *Lantana aculeata*, *Lantana indica* and *Lippia geminata*. The young fruit-clusters attacked are largely destroyed, only a few fruits ripening in each cluster. *P. pusilliactyla* was considered to be a species of some importance in India as a contributory factor in checking the dispersal of lantana seeds by birds. It is, however, not common; its short life-cycle and dependence on flowering plants and its susceptibility to destruction by predators (*Chloridea obsoleta*) and parasites prevent it from becoming a useful agent in the natural control of lantana. It is found also in Burma, Ceylon, Hongkong, West Indies, South America, Hawaii, etc. To the latter country it was introduced from Mexico expressly for the purpose of assisting in the control of lantana by natural enemies.

Beeson and Chatterjee N. C., 1940, *Ind. For. Rec.*, Ent., VI, No. 3, pp. 42, 43, 46, 73, 74.

Fletcher T. B., 1921, *Mem. Dept. Agr. Ind.*, Ent., VI, pp. 19-21, pl. iv.
Rao R., 1920, *Mem. Dept. Agr. Ind.*, Ent., v, No. 6, pp. 280-281, pl. xxxiv.

SATURNIIDAE

Wild Silk Moths are moths of very large size and bright or contrasted colouring usually with transparent patches in both pairs of wings. The larvae are big-bodied distinctly segmented caterpillars, without long hairs, but with swellings bearing short spines. The cocoons vary from loosely woven layers of silk to a thick gut-like network; the silks of two species are of commercial value.

Hampson G. F., 1892, *Fauna Brit. Ind.*, Moths I, pp. 12-29, figs. 7-14.

The genus **Actias** contains the Moon Moths. **Actias selene** occasionally occurs as a pest on *Pyrus* spp., *Juglans regia*, *Lannea grandis*, *Lagerstroemia lanceolata*, *Terminalia paniculata*; it also feeds on *Betula alnoides*, *Coriaria nepalensis*, *Moringa pterygosperma*, *Zanthoxylum acanthopodium*, etc. In the Himalayas it has one or two, in south India several generations per annum.

The genus **Antheraea** contains the Tassar and Muga silkworms.

Antheraea assamensis, The Muga Silkworm, is a many brooded species found wild in Assam and cultivated or semi-domesticated in Eastern Bengal and Assam. It feeds on *Cinnamomum obtusifolium*, *Litsaea* spp., *Machilus odoratissima* and other *Machilus* spp. and *Michelia oblonga*. The eggs are obtained on prepared grass rods which are hung up indoors until the caterpillars hatch and are then transferred to a tree. After the tree has been completely defoliated the caterpillars crawl down the stem and collect on triangular mats which have been placed by the cultivator for the purpose. In these mats the caterpillars are transferred to another tree. The full-grown larvae are placed in trays of dry leaves for pupation. The cocoons which are not stalked are stifled and the silk reeled off. It is white or yellow and weaves into a cloth having a dull bronze or golden colour on account of which it is much valued in India; besides being made up into fabrics it is used for embroidery and artistic weaving as a substitute for gold thread.

Antheraea paphia, The Tassar Silkworm, occurs wild over the greater part of India. It feeds on *Anogeissus latifolia*, *Bassia latifolia*, *Dalbergia*, *Eucalyptus*, *Lagerstroemia indica*, *L. parviflora*, *Shorea robusta*, *Terminalia tomentosa*, *T. arjuna*, *T. paniculata*, *Zizyphus jujuba*, etc., the food-plants of chief importance being the *Terminalias* and sal.

L i f e c y c l e : The eggs are large, thick-shelled and laid in groups on twigs or leaves. The larva is rather bulky, distinctly segmented, and smooth-bodied except for rows of metallic spots and tubercles bearing clusters of short spines; colour pale green

with a yellow line at each side; length 3-4 inches. The cocoon is egg-shaped with a compact surface and formed in rolled up leaves, or suspended from a twig at the end of a thick silken stalk. The female moth is a broad-winged insect with an expanse of 5 inches; colour bright yellow with a circular semi-transparent "eye" in each wing. The male is smaller and browner. There are several races which are one-brooded with emergence in June, July or September, and 2 or 3- brooded with emergence in July–August and again in October–November.

Economic importance: The Tassar Silkworm is not domesticated, and cannot be reared in confinement on a commercial scale. Silk is obtained from two sources, (1) wild cocoons collected in the forests, (2) cocoons obtained from eggs or larvae placed on selected trees in order to concentrate supervision. Sometimes females are bred from wild cocoons and tied to twigs to be fertilised by wild males, but there is no attempt to select and maintain a particular quality of silk or to fix a race or to protect the caterpillars from the attacks of parasites, etc.

The silk is coarse, very strong and of a dark buff colour. It is not spun but reeled off from the cocoon in a continuous thread after the pupa within has been killed by placing in the sun. If the moth is allowed to emerge, the end of the cocoon is torn and the silk spoiled for reeling. The summer cocoon is usually flimsier than the winter cocoon in a double-brooded race. Tassar silk is woven in India mainly for local use; for export it cannot compete with the Chinese Tassar or Shantung Silk (*Antheraea pernyi*). The cocoons are a minor forest product of some importance and are collected in Bombay, Madras, Central Provinces, Bengal, Bihar, United Provinces and Punjab, but the principal tassar-producing districts are Hazaribagh, Ranchi, Palamau, Singhbhum, Sambalpur, Chanda, Bilaspur, Seoni and Raipur. The tassar silk industry is important in the Central Provinces where the annual production of cocoons is valued at 14 lakhs. There are 2 research and seed supply stations in the Chanda and Bhandara districts. The tassar silk weavers of Bengal and the C. P. used to depend largely on Bihar and Orissa for the supply of their raw materials; tassar silk is still produced in larger quantities in Bihar than in any other Province and about 4,000 maunds of cocoons are exported annually. Since about 1935 research has been undertaken at the tassar seed supply station in Bihar and a silk institute has existed since 1922.

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Antheraea roylei feeds on *Betula alnoides*, *Quercus incana*, apple and pear.

Attacus atlas. The Atlas Moth, is the largest of the Indian moths reaching an expanse of 11 inches. The colour of the wings is mainly a rich tawny or purplish-brown and they are divided into two areas by transverse streaks of red, white and black; in the

basal half is a triangular transparent patch. The apex of the forewing is produced with markings vaguely resembling a reptile's head. The caterpillar is pale green with large blue fleshy spines directed backwards, 3 to 4 inches long. The cocoon is not of economic value. It has one or more generations in the year. Among the food-plants are *Ailanthus*, *Berberis*, *Clerodendron*, *Dillenia pentagyna*, *Embelia robusta*, *Lagerstroemia*, *Mussaenda*, *Phyllanthus*, *Schleichera*, *Swietenia*, tea.

Cricula trifenestrata feeds on *Acrocarpus fraxinifolius*, *Anacardium occidentale*, *Bucklandia populnea*, *Careya arborea*, *Cinnamomum* spp., *Mangifera indica*, *Schleichera trijuga*.

Dictyoploca simla is an occasional pest of *Aesculus indica* but feeds also on *Juglans*, *Lagerstroemia*, *Pyrus*, *Salix*, etc.

Loepa katinka feeds on *Dillenia pentagyna* and *Leea sambucina*.

Philosamia cynthia ricini usually known as *Attacus ricini*, The Eri Silkworm, exists wild in Assam, Bihar and Orissa and Bengal where it feeds on *Cinnamomum cecidodaphne*. The many brooded domesticated race is fed on castor leaves (*Ricinus communis*). White silk has been produced by constant in-breeding of individuals producing white cocoons, as those of the wild race are normally reddish-brown. The thread cannot be reeled from the cocoon (as in the case with the mulberry silk-worm) but is carded and spun by hand and then woven. Hence the moths are usually allowed to emerge instead of being killed as is necessary for the mulberry silkworm. Eri silk is largely used in India and rarely exported. In south India it is successfully cultivated on the west coast tracts of Madras. Since about 1935 research has been undertaken at the eri seed supply stations and the silk institutes in Bihar. Some cultivation is done in Assam and Eastern Bengal.

Lefroy H. M., and Ghosh C. C., 1912, *Mem. Dept. Agr. Ind.*, Ent., IV, No. 1, pp 130, figs. 13, pls. IX, Eri silk.
Proceedings All-India Sericultural Conferences.

SCHRECKENSTEINIDAE see HELIODINIDAE

SPHINGIDAE

HAWK MOTHS are readily recognised by their long narrow fore-wings, triangular hindwings and torpedo-shaped body; "the graceful, high-bred appearance of the whole creature can hardly be mistaken" (Bell and Scott). The larvae are destitute of hairs and usually smooth-skinned though some species have tubercles; there is always a horn or tail on the 8th abdominal segment; the largest species run to 3 inches in length. Colour-schemes are developed in great variety often changing from instar to instar; they are abundantly illustrated in the literature on the family [fig. 184]. The population of a species rarely reaches con-spicuously large numbers over an extensive area and epidemics of

hawk moth caterpillars have been observed only occasionally in forests. They are not serious pests of trees although complete defoliation may result locally, but they react readily when crops are grown pure (e.g., *Parum*), and the climate allows a succession of 3 or 4 short generations. Out of a total of 200 species and subspecies and forms of Sphingidae occurring in India, Burma, Ceylon and the Andamans 134 have been found in the East Himalayas (Nepal frontier on the west to Burma frontier on the east, Himalayan plains, Khasi and Naga Hills). The food-plants are found in 60 families of plants, including trees, herbs and grasses. Bell and Scott, 1937, give classified lists of the food-plants of Indian hawk-moths many of which are polyphagous. Eggs are laid singly on the leaves of the food-plant and the caterpillars feed mainly in the early morning and evening for a relatively long larval period. When full-grown they wander some distance before pupating; the pupa rests in a covering of leaves and debris or more usually in a cell in the soil. There are usually 2 broods in the rains with hibernation as pupa in the 2nd brood until the following spring or hot weather in north India; and 3 or 4 generations a year in the tropics.

LITERATURE ON SPHINGIDAE:

Bell T. R. D. and Scott F. B., 1937, *Fauna Brit. Ind.*, Moths, v, Sphingidae, pp. 537, figs. 124, pls. xv.

Hampson G. F., 1892, *Fauna Brit. Ind.*, Moths, I, pp. 65-123, figs. 39-71, Sphingidae.

Scott F. B. 1931, *Journ. Bomb. Nat. Hist. Soc.*, XXXV, 2, pp. 362-381, pls. iii.

— 1933, *tit. cit.*, XXXVI, pp. 938-943, Foodplants of Indian hawk moths.

— 1940, *Journ. Beng. Nat. Hist. Soc.*, XV, pp. 68-71, The hawk moths of Darjeeling and Sikkim.

Acherontia lachesis, a Death's Head Moth, feeds on *Callicarpa arborea*, *C. macrophylla*, *Dolichos lablab*, *Erythrina lithosperma*, *E. indica*, *Jasminum arborescens*, *Lantana aculeata*, *Mussaenda frondosa*, *Stachytarpheta indica*, *Tectona grandis*, *Vitex negundo*. In north India there are 3 generations with moths in April, May completing the life-cycle in 7 weeks and the progeny of these maturing in September. Larvae from eggs hatching in September feed till mid-October and then enter the soil for hibernation, pupating after about 5 months; the pupal period is 2 or 3 weeks in April, May and in the monsoon.

Beeson and Chatterjee N. C., 1940, *Ind. For. Rec.*, Ent., VI, No. 3, p. 75.

Acherontia styx, the common Death's Head Moth [fig. 157, No. 5] (so-called from the markings resembling a skull on the prothorax) is a polyphagous species feeding on *Clerodendron phlomidis*, *C. siphonanthus*, *Jasminum arborescens*, *Millingtonia hortensis*, *Spathodea campanulata*, *Stereospermum chelonoides*, *Tectona grandis*, *Vitex negundo*, wild creepers and various agricultural crops. There are 2 to 4 generations per annum. In north India 3, with moths in March–April completing the cycle in

7 weeks by May and the progeny of these maturing in September; larvae pupating in October overwinter as pupae in the soil and transform to moths in the spring.

Acosmeryx anceus and **A. socrates** feed on *Dillenia pentagyna*, *Leea sambucina* and *Vitis indica*.

Agnosia microta defoliates *Anogeissus latifolia*. **A. orneus** feeds on *Grewia asiatica* and *Grewia tiliaefolia*. The life-cycle is annual with moths in June, July

Cephonodes hylas and **C. picus** (Clearwing or Humming Bird Hawk Moths) feed on *Adina cordifolia*, *Gardenia florida*, *Hymenodictyon excelsum*, *H. obovatum*, *Randia dumetorum*, *Stephegyne diversifolia*, *S. parvifolia*, *Tectona grandis* and *Xylia dolabriformis* (principally on Rubiaceae). The young larva of *C. hylas* is of a uniform pale green colour and the next instar develops a broad longitudinal dorsal black band. There are 5 instars and the last two are orange-red to chocolate with a dark dorsal band and yellowish-white dorso-lateral streaks and red bordered spiracles. Descriptions of the larva are given by Bell and Scott, 1937, p. 248, pl. 3, figs. 8, 9, and Sevastopulo, 1939, *Journ. Bomb. Nat. Hist. Soc.*, XLI, pp. 315–317, XLII, p. 43. In April the larval and pupal periods are about 3 weeks each. The pupal period is 11 days in July and 13 days in September.

Clanis bilineata feeds on *Millettia atropurpurea*, *Pongamia glabra* and *Pterocarpus marsupium*. **C. phalaris** feeds on *Butea frondosa*, *Millettia atropurpurea*, *Mucuna pruriens*, *Pongamia glabra*, *Pterocarpus marsupium*, *Xylia dolabriformis*, *X. xylocarpa*. The larva is often common in the monsoon on *Xylia*; it assumes a "sphinx" attitude when resting and strikes sideways with the head when molested. Larval descriptions are given by Bell and Scott, 1937.

Cypa decolor feeds on *Dipterocarpus tuberculatus*.

Deilephila nerii feeds on *Holarrhena antidysenterica*, *Nerium odorum* and *Tabernaemontana coronaria*. Caterpillars pupate in the soil in a silk-lined cell; those which are mature in April produce moths after 2 weeks. Another generation with full-grown caterpillars in August has a pupal period of 2 weeks. Caterpillars occurring in November may pupate in that month and produce moths in December after a pupal period of 7 weeks. Pupation in December gives moths in March after 12 weeks. Pupation in February gives moths in March after a pupal period of 6 or 5 weeks. The mature caterpillar is green with a yellow tail or dark above and pink below with a pink tail. See Bell and Scott, 1937, for technical description.

Macroglossum affictitia and several other species of *Macroglossum* feed on *Strychnos nux-vomica* and *S. nux-blanda*. Other species are associated with *Morinda* spp. and Rubiaceae. There are several generations a year with pupal periods of 7–9 days.

Marumba dyras feeds on *Bombax malabaricum*, *Bridelia* spp.,

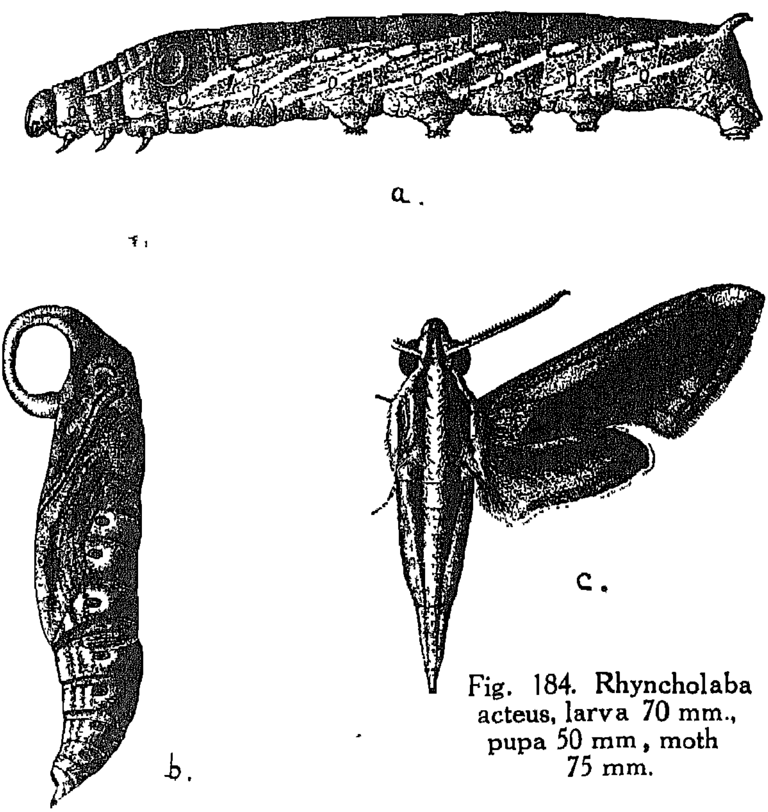

Fig. 184. Rhyncholaba acteus, larva 70 mm., pupa 50 mm, moth 75 mm.

Grewia microcos, Helicteres isora, Kydia calycina, Sapindus trifoliatus, Schleichera trijuga, Sterculia villosa. A generation occurs early in the monsoon pupating in August and yielding moths after a fortnight. The early stages are described by Bell and Scott, 1937, pl. III, fig. 3. **M. indicus** on *Bombax, Grewia, Helicteres* and *Sterculia.* **M. spherchius albicanus** feeds on *Quercus incana* and **gigas** on *Quercus griffithii* and *Q. serrata.* In the mountains there is single generation starting at the end of May or early in June which feeds until the end of July when the pupal period becomes a resting stage and lasts for 10 months. Bell and Scott, 1937, pl. XIII, fig. 8.

Oxyambulyx sericeipennis defoliates *Betula alnoides, Buchanania latifolia, Engelhardtia spicata, Juglans regia, Myrica nagi, Rhus insignis* and *Xylia dolabriformis.* **O. subocellata** feeds on *Buchanania latifolia* and *Lannea grandis.* The larva is described by Bell and Scott, 1937, pl. VIII. **O. substrigilis** feeds on *Aglaia littoralis* and *Dipterocarpus tuberculatus.* The larva is described by Bell and Scott, 1937, pl. II.

Parum colligata feeds on *Broussonetia papyrifera.* In Burma it occurs in epidemic numbers completely defoliating plantations of *Broussonetia* and seriously complicating the cultivation of the paper mulberry in pure crops.

Polyptychus trilineatus feeds on *Cordia myxa*, *C. obliqua*, *C. rothii*, and *Ehretia laevis*. The life-cycle is about 53 days (egg 5, larva 30, pupa 18 days). The larva is described by Bell and Scott, 1937, pl. ii.

Psilogramma menephron is recorded occasionally in abundance as a pest of *Aporosa villosa*, *Gmelina arborea* and *Tectona grandis*. It normally feeds on *Heterophragma adenophyllum*, *Jasminum arborescens*, *Ligustrum* sp., *Nyctanthes*, *Olea dioica*, *Stereospermum chelonoides*, *Vitex negundo*. The life cycle is annual. Larvae pupate in September and produce moths after a pupal period of 18 days; those pupating in November give rise to moths in May–June. The early stages are described by Bell and Scott, 1937, pls. i, viii, xiii.

Rhyncholaba acteus [fig. 184] feeds on species of Aroideae and *Vitis*. A common widespread species in the Indian region. The stages are described by Bell and Scott, 1937, pls. vi, vii.

Sataspes infernalis feeds on *Albizzia lebbek* and *Dalbergia volubilis*. **S. scotti** on *Dalbergia sissoo*.

Thamnoecha uniformis feeds on *Pinus longifolia*.

Theretra oldenlandiae feeds on *Careya arborea* and *Morinda tinctorea*.

SYNTOMIDAE

Beeson and Chatterjee N. C., 1940, *Ind. For. Rec.*, Ent., vi, No. 3. pp. 75-76

Chatterjee N. C., 1935, *tit. cit.*, i, No. 10, pp. 198, 199.

Fletcher T. B., 1925, *Catalogue Ind. Ins.*, Part 8 Amatidae.

Hampson G. F., 1892, *Fauna Brit. Ind.*, Moths i, pp. 209-228, figs. 136-143, Syntomidae.

Ceryx imaon feeds on *Lantana aculeata*; the life-cycle is about 40 days in the hot season.

Syntomis cyssea feeds on various agricultural crops and on the flowers of *Lantana aculeata*. In north India in June–July the life-cycle takes 37–43 days (egg 2–4, larva 29–31, pupa 6–8 days). The moth is shown in fig. 157, No. 32, the larva in fig. 156, No. 5. **S. passalis** feeds on *Santalum album* passing through 8 or more generations a year in south India.

TERAGRIIDAE see INDARBELIDAE

TINEIDAE

THIS small family of Microlepidoptera includes species feeding on decaying or dead organic matter such as dead bark, vegetable dust and rubbish, wool, hair, feathers and horn as well as living plant-tissues. The larvae use various kinds of bags [fig.

185] or tubes made of silk and dust to protect themselves; a few species are wood-borers.

Fletcher T. B., 1921, *Mem. Dep. Agr. Ind. Ent.*, VI, pp. 181-194, pls. liii-lvii, Tineidae.

— 1933, *Imp. Counc. Agr. Res., Sci. Mon.* No. 4, pp. 73-82, pls. lxxi-lxxiii, Tineidae.

Crypsithyris longicornis. The larva makes an elongate oval case about 10 mm. long of grey silk and dust in which it walks about on the floor and walls of houses; it feeds on dead organic matter and possibly size in whitewash. Fletcher, 1921, *tit. cit.*, pl. lvii, fig. 2.

Demobrotis cuniculata and **Drimylastis telamonia** breed under the bark of logs of numerous species of trees, where the larvae feed on decayed vegetable matter.

Gerontha captiosella is one of the lesser heartwood-borers of *Shorea robusta.* The moth has narrow elongate wings with an expanse of 1—1½ inches, forewing silvery grey speckled with black, hindwing fuscous, abdomen and hind legs long and hairy. The eggs are laid on the bark of the main bole and branches of the tree and the early larval life is apparently spent in feeding on the bark. The tunnels are grouped closely in clusters with their mouths over an area of about 20 square inches to one square foot. The larval tunnel is sinuous and runs horizontally from the outer bark directly into the heartwood without any expansion or chamber in the bark; its horizontal diameter is about half the vertical diameter. At the end the tunnel turns at right angles and forms an oblique or vertical pupal chamber about an inch long which is lined with a fine whitish silk layer and is closed at the neck with a partition of silk faced externally with black excreta or carbonised bark-fragments. The pupal chamber is completed and closed by February. In order to release the moth the pupa climbs back along the tunnel and emerges halfway from the exit-hole in the bark (as do many species of wood-boring Lepidoptera). After the emergence of the moth, which takes place in May–July, the pupal skin remains stuck in the exit-hole, which is oblong oval. This species also bores the wood of *Ailanthus malabarica*, *Duabanga sonneratioides*, *Erythrina indica* and *Manihot glaziovii.* It occasionally occurs in epidemic abundance as the dominant borer in drought seasons and is associated with a bark-fungus, *Hypoxylon annulatum* in *Shorea robusta.*

Fletcher T. B., 1933, *tit. cit.*, pp. 80, 81, pl. lxxii.

Hapsifera rugosella breeds under the dead bark of logs of very many species of trees and probably feeds on decayed bast tissues.

The genus **Melasina** comprises species which in the larval stage live in the soil in tunnels lined with silk; the larva is about an inch long and feeds above ground on dead leaves and decaying vegetable matter which is reached by extending the silken tubes over

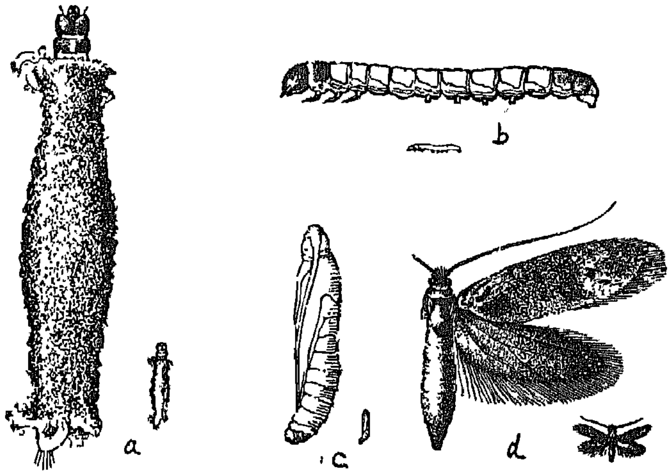

Fig. 185. Tinea pellionella.

the surface of the soil.

Melasina campestris or **M. energa** or an allied species lives in sandy soil in *Casuarina equisetifolia* plantations in Madras and, by girdling the stem just above or below ground-level under the shelter of a silken tube, damages the young seedlings. The silken tubes are covered externally with particles of sand and fragments of humus and may reach a length of several feet above ground; they descend vertically into the soil for several inches. Pupation occurs in a tough cocoon at the end of a vertical tunnel in the sand. If the seedling is girdled above ground-level it may send out a new shoot after the plant has been watered. Sometimes the silk tube is constructed up the stem nearly to the top and the branchlets are gnawed.

Fletcher T. B., 1921, *Mem. Dept. Agr. Ind.*, Ent., VI, pp. 181-183, pl. liii.

Ptychoxena tephrantha breeds under the bark and in the wood of *Buchanania latifolia* and *Dipterocarpus turbinatus*. The life-cycle is annual with moths in May, June.

Tinea pellionella [figs. 185, 156, No. 29] is a common clothes-moth in India. The larva feeds on woollen clothes, carpets, furs and skins, feathers, shikar trophies, museum specimens, etc. It is a pest in dwelling houses, warehouses, shops, military stores, etc. The larva, 6 mm. long, lives in a flattened smooth silk case which it drags about and in which it pupates. It breeds throughout the year except in districts with a definite winter. Fletcher, 1921, *lit. cit.*, pl. lvi, fig. 2.

THYRIDIDAE

Hampson G.F., 1892, *Fauna Brit. Ind.*, Moths, I, pp. 352-371, figs. 241-250, Thyrididae.

Addaea trimeronalis defoliates *Mallotus philippinensis*; the pupal period is over a month in January, 21 days in February falling to 15 days in March from caterpillars feeding through the cold season.

Betousa stylophora. The larva lives in a gall on the stem of *Phyllanthus emblica*; reddish frass is extruded through a hole at one end. Fresh galls are generally formed in June to August and are full sized (23 × 10 mm.) at the beginning of the cold weather. The larva emerges at the beginning of the hot weather and pupates in a cocoon formed of webbed-up leaflets. The pupal period lasts 8 to 10 days in May and June. The life-cycle is described and the stages and gall, etc. are figured by Bose B. B., 1935, *Ind. Journ. Agric. Sci.*, v, pp. 738–739, pls. xxxiv, xxxv, figs. 1–7.

Brixia emblicalis defoliates *Jambosa formosa* and *Lagerstroemia tomentosa.*

Dysodia ignita feeds on *Croton oblongifolius.*

Herdonia osacesalis feeds on *Lagerstroemia flos-reginae.*

Rhodoneura loceusalis. The larva feeds on the webbed-up leaves and bores into the tender top-shoots of *Loranthus longiflorus*. Pupation occurs in a cocoon in webbed-up leaves. The pupal period varies from 9 to 18 days. There are several generations in the year.

Bose B. B., 1935, *Ind. Journ. Agric. Sci.*, v, pp. 740-741, pl. xxxvi, figs. 8-10.

Rhodoneura myrsusalis feeds on the foliage of *Achras sapota* and *Bassia latifolia.*

Striglina scitaria, a widespread species, feeds on the foliage of *Albizzia procera*, *Bauhinia racemosa*, *Cassia fistula*, *Careya arborea*, *Derris elliptica*, *Melastoma malabathricum*, *Millettia atropurpurea*, *Xylia dolabriformis*. It defoliates *Xylia dolabriformis* in Burma in association with *Maruca testulalis* (Pyralidae).

TORTRICIDAE

Fletcher T. B., 1921, *Mem. Dept. Agr. Ind.*, Ent., vi, pp. 34-43, pls. viii, ix, Tortricidae.

— 1932, *Imp. Counc. Agr. Res., Sci. Mon.* No. 2, pp. 14-18, pls. ix, x.

Adoxophyes privatana, a widely distributed species, occurs in India on *Glycosmis pentaphylla* and *Lantana aculeata.*

Cacoecia micacaeana. Several varieties of this species are recognised, var. **compacta** occurs on *Cassia fistula*, *Cedrela toona*, *Chrysanthemum*, *Lantana*, *Mallotus philippinensis*, *Mangifera indica*, *Morus alba*, *M. indica*, *Salix*, and *Santalum album*; the leaves are webbed together and the larva feeds on the epidermis and mesophyll tissue from the inside surface.

var. **machlopis** occurs on *Lantana aculeata* eating the fruits.

var. **micacaeana** typica occurs on *Acacia arabica*, *Albizzia*

procera, *Aster*, *Bombax malabaricum*, *Bucklandia populnea*, *Cedrela toona*, *Cosmos*, *Dalbergia sissoo*, *Dillenia indica*, *Gmelina arborea*, *Lantana aculeata*, *Michelia champaca*, *Morus indica*, *Santalum album*, *Tectona grandis*, *Terminalia tomentosa* and *Ixora* and various cultivated annuals. The caterpillar feeds on the flowers, fruits and foliage of several plants such as *Cedrela*, *Dalbergia*, *Dillenia* and *Lantana*; on other foodplants it is known chiefly as feeding on the leaves. The larva and pupa are described by Fletcher, 1921, *tit. cit.*, p. 38 (as *Cacoecia epicyrta*).

var. **obscura** occurs on *Eugenia jambolana*, *Lantana aculeata* and *Millettia auriculata*.

Cacoecia isocyrta feeds on *Acacia arabica*, *Cedrela toona*, *Litsaea polyantha* and *Santalum album*, eating the leaves; the pupal period is 4 to 6 days in July-September. **C. solida** feeds on the leaves of *Cedrela toona*.

Epagoge retractana occurs on *Acacia arabica* and *Chrysanthemum*.

Homona coffearia feeds on *Derris elliptica*, *Eugenia jambolana*, *Lantana aculeata* and on coffee and tea bushes; Fletcher, 1921, *tit. cit.*, pp. 35–37.

Homona phanaea rolls the leaves of *Michelia champaca* and pupates inside the roll. The pupal period is 8 days in November.

Peronea epidesma, a widespread species, rolls and binds together the young leaves of *Polyalthia longifolia* feeding on the inner layers of the shelter thus formed. The larva is about ½ an inch long and the moth less than one inch in expanse; pupation occurs in a thin cocoon in the rolled leaf. Fletcher, 1921, *tit. cit.*, pl. ix.

Ulodemis falsa feeds on *Vitex negundo*. **U. trigrapha** feeds on the leaves and flowers of *Lantana aculeata* and bores into apple fruits. The stages are illustrated by Fletcher, 1921, *tit. cit.*, pl. lviii, fig. 2.

URANIIDAE

Hampson G. F., 1895, *Fauna Brit Ind.*, Moths, III, pp. 110-120, figs. 56-65, Uraniidae

Urapteroides astheniata defoliates *Endospermum malaccense* in Malaya. It is most abundant in June, July, the driest period of the year. The pupal period is about 8–10 days and the life-cycle is about 2 months

1937, *Malayan Forester*, VI, p. 267, 1940, *tit. cit.*, IX, pp. 38, 39.

XYLORYCTIDAE

Fletcher T. B., 1921, *Mem. Dept Agr. Ind*, Ent., VI, pp. 112-115, 205, pls. xxvi, lxiii, Xyloryctidae.

— 1933, *Imp. Counc. Agr. Res., Sci. Mon.*, No. 4, pp. 13-17, pls. x-xii, Cryptophasidae.

Acria emarginella feeds on the leaves of *Morus alba*, *Ricinus*

communis and *Tectona grandis*, appearing in the autumn to winter in north India.

Aeolanthes sagulata defoliates *Cedrela toona*, *Ougeinia dalbergioides* and *Salix tetrasperma* binding the leaves. The pupal period is 11–14 days in April and 6–8 days in August; in the cold season the larval life is prolonged and the pupal period is about 20 days. It has been observed feeding on *Tectona grandis*.

Fletcher T. B., 1933, *tit. cit.*, p. 13, pl. x.

Nephantis serinopa is a pest of palms, coconut, palmyra, etc. in Southern India, Bengal and Burma. The eggs are laid in small batches on palm leaves. The larva feeds under a gallery of silk and excrement eating away the tissue until the leaf is reduced to a thin membrane and dries up; sometimes the leaflets gradually curl up along their whole length and form a tube within which all green tissue is consumed; larval length about 1 inch, colour pinkish with faint paler lines along the body. Larvae occur over the greater part of the year. Pupation takes place on the damaged leaves. The attacked trees have a faded appearance and take about a year to recover but occasionally the results are fatal.

Fletcher T. B , 1933, *tit. cit.*, p. 15, pl. xii (coloured), previous literature.
Hutson J.C., 1933, *Trop. Agr.*, LXXXI, pp. 67-69, 1 pl. The coconut caterpillar.

YPONOMEUTIDAE

Fletcher T. B., 1921, *Mem. Dept. Agr. Ind.*, Ent., VI, pp. 132-135, xxxii, Hyponomeutidae.
— 1928, *Catalogue Ind. Ins.*, Part 17, Yponomeutidae.
— 1933, *Imp. Counc. Agr. Res.*, *Sci. Mon.* No. 4, pp. 33-38, pls. xxx-xxxii, Yponomeutidae.

Atteva fabriciella and **A. niveiguttata** a defoliator of *Ailanthus excelsa*. The larvae live gregariously under a silk web spun over the leaves and shoots. The full-grown larva is about ⅘ths of an inch long, greenish-grey in colour. Pupation occurs in a loose cocoon in the common web; pupal period about 7–10 days. The former species also feeds on *Boswellia serrata*.

Ethmia acontias defoliates *Ehretia laevis* and *Cynoglossum lanceolatum*. **E. assamensis** defoliates *Ehretia acuminata*, *E. serrata* and *Rhamnus purpureus*. Moths of the first generations appear in March–April from larvae which hibernate or are very inactive from November onwards. **E. systematica** (*Azinis hilarella*) defoliates *Ehretia laevis* and *Tectona grandis*. The moth is pale grey with several distinct black dots. The larvae, 20 mm., feed gregariously on young foliage under white silk webs; the web is usually placed along the midrib of the leaf drawing the two edges together. When disturbed the larva drops to the ground through an .opening at each end of the web. Pupation occurs in a cocoon under the web. The pupal period is 8 to 10 days in April and 6 to 8 days in May to July.

ZYGAENIDAE

Fletcher T. B., 1925, *Catalogue Ind. Ins.*, Part 9, Zygaenidae.
Hampson G. F., 1892, *Fauna Brit. Ind.*, Moths, I, pp. 228-289, figs. 144-197.

Cyclosia papilionaris defoliates *Aporosa roxburghii* and *Baccaurea sapida*.

Himantopterus dohertyi feeds on *Quercus griffithii*. Eggs are laid in a group on the underside of the leaf, each egg separately covered with erect hairs. The newly hatched larvae feed side by side in a row on the under surface of the leaf. Larvae derived from eggs laid in July mature in October and become moths in the following June; the life-cycle is thus annual. The moth, 25-35 mm. has a narrow hindwing terminating in a tail or long filament.

Histia rhodope feeds on *Bischofia javanica* and *B. sinensis*.

Phauda flammans. This slug-caterpillar, about ½ inch long, resembling a bird's dropping, is a defoliator of *Ficus glomerata*. Two broods occur in the hot weather and rains, the last pupating in October and overwintering as a larva in a cocoon of tough brownish silk until April.

Trypanophora semihyalina. The larva is a slug-caterpillar [fig. 156, No. 21] varying in colour with markings of black, pink, brown and blue; on each segment is a series of fleshy swellings carrying 2 or 3 bristles; length ½ an inch. The cocoon is a flattened covering to the pupa, which emerges at one end to release the moth. The moth is black with numerous transparent spots; expanse less than 1½ inches [fig. 157, No. 23]. The pupal period in February is 3-4 weeks, in March is 2-3 weeks and in July-August is 11 days. Larvae which form cocoons in December produce moths in March. It occurs occasionally as a defoliator of *Shorea robusta*, *Terminalia catappa* and *T. tomentosa* and also feeds on *Barringtonia acutangula*, *Careya*, *Holarrhena*, *Lagerstroemia* and *Zizyphus*.

NEUROPTERA

THIS is a small Order, not as large as several families of beetles or moths. Although it includes many species that are predaceous and beneficial to mankind, e.g., the ASCALAPHIDAE, CHRYSOPIDAE, CONIOPTERYGIDAE, HEMEROBIIDAE, MANTISPIDAE, MYRMELEONIDAE, NEMOPTERIDAE, RAPHIDIDAE, and SIALIDAE, it has not received the attention it merits in the Indian region. The only general survey of the neuropterous fauna of a forest tree is that undertaken for *Santalum album* in south India. For key to neuropterous families see Fletcher, 1925.

LITERATURE ON NEUROPTERA:
Banks N., 1933, *Ind. For. Rec.*, XVIII, vi, Neuroptera of sandal (9).
Chatterjee N. C., 1934, *tit. cit.*, XIX, v, Neuroptera of sandal (15).
Fletcher T. B., 1925, *Agr. Res. Inst., Bull.* 162, pp. 41-43, Tentative keys to orders and families of Indian insects.

ASCALAPHIDAE

Helicomitus dicax feeds in the larval stage on small caterpillars, plant-sucking bugs, silverfish, etc. The life-cycle normally lasts a year but may be considerably extended; the egg-stage takes 4 days and the pupa 2–3 weeks, the remainder of the life-cycle being passed as a larva. It is not an active hunter, preferring to disguise itself with dust and rubbish and lie in wait on the ground for passing prey. The life-history is described by C. C. Ghosh, 1913, *Journ. Bomb. Nat. Hist. Soc.*, XXII, pp. 643-648, pl.

CHRYSOPIDAE

GREEN lace-wings are predaceous as larvae and adults on small caterpillars, green-fly and other plant-sucking bugs, mites, etc. The eggs are laid in clusters each on a hair-like stalk on foliage. The larva is aggressively carnivorous, piercing its prey with specialised mandibles which chew and suck out the body-fluids. It has on its back long spines or bristles which entangle the dead dry bodies of its prey and thereby camouflage it. With each moult it sheds the accumulation of skins and rubbish and starts a new covering. At the end of the 3rd or 4th instar it pupates in a small white oval cocoon. The pupa, when escaping, cuts a circular lid at one end of the cocoon, and crawls away for a short distance before the imago is released. The life-cycle lasts for 4–8 weeks. The seasonal abundance of the adult of **Chrysopa khandalina** in south India shows peaks in December, January and March, April and August, September, indicating 3 main breeding-seasons.

Chatterjee N. C., 1934, *Ind. For. Rec.*, XIX, v, p. 5, fig. 4.

HEMEROBIIDAE

SIMILAR feeding-habits to those of the Chrysopidae occur in this family but many species are larger and have longer life-cycles. The seasonal abundance of the adult of **Micromus australis** in south India reaches its maximum in December–February and is at its minimum in April–August; the generation is possibly annual with a long emergence period.

Chatterjee N. C., 1934, *lit. cit.*, p. 3, fig. 2.

ODONATA

DRAGONFLIES form a very small but clearly defined Order of insects. There are about 500 species in the Indian region monographed by Fraser in a series of papers in the *Journ. Bomb. Nat. Hist. Soc.* and the *Fauna of British India*. Economically dragonflies are of great importance in destroying mosquitoes and other noxious flies. Life in the tropics would soon become unbearable were it not for the beneficent work of vast numbers of

dragonflies acting as scavengers of the atmosphere (Fraser). Some species which take to the wing only after dark or at dusk live entirely on mosquitoes. Small winged insects of all sorts are assiduously hunted by day. Dragonfly larvae are aquatic and predaceous, including in their diet the larvae of mosquitoes; *Anopheles* larvae are eaten by, e.g., **Anax guttatus** (Aeshnidae), **Ceragrion coromandelianum, Ischnura senegalensis** and **Pseudagrion microçephalum** (Coenagriidae), **Ictinus rapax** (Gomphidae), **Bradinopyga geminata** and **Crocothemis servilia** (Libellulidae). The life-cycle varies from about 3 months (**Lestes,** Coenagriidae); the larger forms take 1 to 3 years to reach maturity.

LITERATURE ON ODONATA:

Fraser F. C, 1933-1936. *Fauna Brit. Ind.*, Odonata, I, pp. 423, figs. 180, (Coenagriidae), II, pp. 398, figs. 120, pls. 4 (Agriidae, Gomphidae); III, pp. 46, figs. 125, pls. 2 (Cordulegasteridae, Aeshnidae, Libellulidae). And a series of papers previously issued in the *Journ. Bomb. Nat. Hist. Soc.*

ORTHOPTERA

THE ORDER ORTHOPTERA

UNDER the Linnean name ORTHOPTERA it is convenient to assemble many groups that are now ranked by taxonomists as orders or suborders, i.e., the locusts and grasshoppers, crickets, cockroaches, leaf and stick insects, mantises, etc. of which about 18,000 have been described in the whole world. The Indian fauna has been monographed in the *Fauna of British India* in only one family, the Acrididae, and work is in progress on the Gryllidae by Chopard and Tettigoniidae by Henry.

The majority are herbivorous or scavengers; a few are predaceous on other insects. None are aquatic, social or parasitic on living plants or animals. Those of interest in forestry are (1) defoliators or (2) injurious to young seedlings or (3) predaceous on pests. The eggs are either laid singly, or in a cluster in the soil, or in a mass protected by a special secretion, or in a baglike receptacle (*ootheca*). The larva on hatching more or less resembles the adult and in the later stages differs chiefly in size, colour, and absence of functional wings and reproductive organs. There are 6–8 instars, and the wings appear as small buds or flaps increasing in development with each moult.

The following synopsis includes the families (s. l.) dealt with in this book:—

Blattidae
Mantidae
Phasmidae
Tettigoniidae
Gryllidae
Acrididae
Gryllacridae

For keys and characters of the orthopteroid complex see Fletcher, 1925.

LITERATURE ON ORTHOPTERA:

Chopard L. and Chatterjee N. C., 1937, *Ind. For. Rec.*, Ent., III, No. 1, pp. 5-30, Orthoptera of sandal (31).

Fletcher T. B, 1921, *Catalogue Ind. Ins.*, Part I, Acrydidae (Tettigidae).

— 1925, *Agr. Res. Inst. Bull.* 162, pp. 21-27, Tentative keys to orders and families of Indian insects.

Kirby W. F., 1914, *Fauna Brit. Ind.*, Orthoptera, Acridiidae, pp. 1-276, figs.

Uvarov, B. P., 1927, *Spol. Zeyl.*, XIV, pp. 85-114, Some Orthoptera of the families Mantidae, Tettigoniidae and Acrididae from Ceylon.

— 1932, *Journ. Bomb. Nat. Hist. Soc.*, XXVIII, pp. 719-738, Records and distribution of Orthoptera from S. W. Asia.

— 1933, *tit. cit.*, XXIX, pp. 643-652, Some new or interesting Orthoptera from Persia, Baluchistan and western India.

ACRIDIDAE

THE family ACRIDIDAE comprises the true Locusts and the Shorthorned Grasshoppers, insects readily recognisable by their antennae usually shorter than the body length and long leaping hindlegs; they vary in size from ¼–2 inches.

Ecology

The female deposits eggs in a deep hole dug in the soil by means of the ovipositor, which has 2 pairs of valves. During the process of digging the abdomen is much elongated. Ten to over 100 eggs are laid in one hole and are cemented together with gum into a more or less cylindrical packet an inch or more in length. The larva when it hatches from the egg is enclosed in a transparent membrane; it pushes its way through the soil above the egg-packet by wriggling worm-like movements and on reaching the surface of the ground immediately moults. The young larvae, known as *nymphs* or *hoppers*, have 5 to 7 moults, and conspicuous wing-stubs or rudiments appear at the 3rd or 4th moult. In the rudimentary wings of hoppers the 2nd pair covers the 1st pair and only longitudinal veins are perceptible.

Grasshoppers feed on vegetation in all stages of their lives (except the egg and hatching larva). Most species have a wide range of food-plants among which Gramineae are important. When feeding on trees the leaf-stalks and edges of the leaves are nibbled or ragged so that more foliage falls to the ground than is eaten. Several species are pests of seedlings and saplings of trees. The length of the life-cycle varies from one annual generation to 3 broods a year. The cold weather or the hot weather months or both may be passed in the egg-stage; the life of the adult grasshopper is often much prolonged.

Locusts: In India 3 species of Acrididae, *Schistocerca gregaria*, the Desert Locust, *Locusta migratoria*, The Migratory Locust and *Patanga succincta*, the Bombay Locust, have the faculty of collecting together in bands or armies in the hopper-

stage, and later in swarms as adults which migrate by flight for vast distances from their original habitat. These migratory species of grasshoppers are known as locusts.

Phases: There is no substantial difference between solitary grasshoppers and gregarious locusts: most species of locusts have two definite or extreme biological phases, a *solitary* or individual phase as well as a migratory or *gregarious* phase. Transitional forms occur when the transformation is from the solitary towards the gregarious phase, or when the tendency is in the opposite direction. In the past extreme forms have been mistaken for distinct species owing to their widely different colouration, structure, physiological reactions and habits.

The gregarious phase is the result of crowding, i.e., the density of population within a restricted area is the factor causing the transformation. The conditions under which the normally scarce solitary locusts get crowded arise from the weather (particularly rainfall) and the food-supply; these critical factors are discussed later in the accounts of the species, pp. 715, 716, 718. The result of this transformation is a compact accumulation of gregarious locusts differing from the original solitary ones in the high intensification of all activities under the influence of mass psychology; there is a striking tendency to remain in close proximity to each other which ensures the existence of a swarm as a single unit.

Armies of hoppers: This tendency determines the marching of hoppers in armies. A band once started on its march positively cannot stop, since the hoppers owing to their gregariousness, strive to keep as close as possible to each other and produce continuous mutual stimuli resulting in jumps and crawling. The band therefore *must move*, regardless of where this movement may lead it, and the result is the blind march of masses of hoppers. As the result of chance encounters the fusion of separate bands takes place and enormous armies with a frontage of several miles may be formed which pass over or around all obstacles, even canals and rivers.

Swarms of locusts: When the adult stage is reached desultory flying of individuals preceeds the formation of small flying swarms which gradually increase in size and take more prolonged flights. Eventually the flights of large swarms take them long distances from the breeding-grounds. A single flight may last for 1 to 3 days and nights without settling and the period of migration may continue for several months. Locust swarms recognise no boundaries. The migration of *Schistocerca gregaria* carries it from beyond the northwest frontier of India eastwards as far as Assam. *Patanga succincta* spreads from the west coast of Bombay far over the Peninsula. In the short period of 5 generations the tropical migratory locust was able to

cross Africa from west to east, and in the next 3 generations spread over the whole of East Africa and crossed the continent diagonally from northeast to southwest. The immediate cause of locust migrations is not shortage of food or over-population of the breeding-grounds but is due to a physiological stimulus possibly analogous to that causing the nuptial flights of termites and ants. It is closely connected with the rate of development of the sexual products, which in solitary forms of locusts are almost completely developed on reaching the adult stage, and in swarming forms are comparatively immature, so that a migratory flight is necessary for the full development. It is prolonged until the females are mature enough to oviposit. Often it culminates in mass-suicide when swarms fly out into the open sea, or meet bad weather, or halt and oviposit in localities quite unsuitable for the perpetuation of the species.

Economic importance

Locusts are not omnivorous but where the swarms settle the vegetation is often almost wholly destroyed, the zone of destruction being sharply limited. Agricultural crops as well as forest and natural vegetation are eaten. In addition to the damage done by complete defoliation and by destruction of new shoots and flowers and by nibbling the bark of twigs, large branches of trees may be broken off by the weight of the locusts settled on them. They are also injurious in that houses and bazaars are invaded, the excrement fouling exposed food-stuffs; their dead bodies decay and water-supplies are poisoned often with very serious consequences to human life. Plagues of locusts cause an immense amount of damage when and where they occur but, in spite of the spectacular effect, it is probable that the total damage done in India is much less than that due annually to any one of the major forest insect pests. The visitation of the Desert Locust, *Schistocerca gregaria*, in 1929 is estimated to have caused a loss of from 3 to 5 crores of rupees in North India. During the last outbreak of the tropical migratory locust in Africa the losses, direct and indirect, amounted to seven million pounds sterling.

The origin and periodicity of the locust outbreaks in India are discussed on pages 715, 716, 718.

I n t e r n a t i o n a l r e s e a r c h: Since about 1930 investigation of the locust problem has been developed on an international scale as little progress could be expected from its study on a narrow territorial basis. The first international Locust Conference was held in Rome in 1931 where a common policy of investigation of the problem was accepted and the Imperial Institute of Entomology in London was designated as the international centre for anti-locust research. Later conferences have been attended by delegates from 20 countries. Vast areas have been explored in Africa and India by special locust research orga-

nisations in those countries. The Imperial Council of Agricultural Research financed the Locust Bureau for India. The fact has been established that invasions of each species of locust arise from relatively restricted outbreak centres where, alone, the peculiar ecological conditions permit the transformation from the solitary phase to the gregarious phase. These migrations which formerly appeared so capricious in character are, in fact, subject to a certain irregular periodicity in their development. Widespread invasions of whole countries and continents are preventable by concentrating early efforts in the areas which can be regarded as original sources of the swarms.

LITERATURE ON ACRIDIDAE AND LOCUSTS:

Henry G. M., 1933-1940, *Spolia. Zeyl.*, XVII-XXII, Systematic papers on Ceylonese Acrididae.

Kirby W. F., 1914, *Fauna Brit. Ind.*, Orthoptera, Acridiidae, pp. 1-276, figs.

Ramachandra Rao Y, 1941, *Proc. 28th Ind. Sci. Congr.*, Pres. Address Ent., Some observations on the periodicity of locust invasions in India (*Summary in Ind. Journ. Ent.*, II, pp. 193-199.)

Uvarov B P., 1928, *Locusts and grasshoppers.*

— 1927, *Rec. Ind. Mus.*, XXIX, pp. 233-239, Distribution records of Indian Acrididae.

— 1936, *Current Sci.*, pp. 191-193, Locusts as an international problem.

Acrida gigantea includes *Shorea robusta* among its food-plants and is sometimes injurious in sal taungya plantations. **A. turrita** occasionally feeds on stump-plants of *Tectona grandis.*

Acridella nasuta is a pest of seedlings of *Pinus excelsa* and *P. longifolia* early in the rains.

Aulacobothrus luteipes feeds on *Tectona grandis* foliage.

Aularches miliaris, The Spotted Locust. This grasshopper occurs throughout India in the moister regions and feeds on many species of trees and shrubs in jungle land, including *Artocarpus integrifolia*, *Butea frondosa*, *Cocos nucifera*, *Colebrookia oppositifolia*, *Erythrina indica*, *Flemingia* sp., *Hevea braziliensis*, *Mangifera indica*, *Strychnos nux-vomica* and *Tectona grandis.*

It has been observed in abundance in teak plantations in Travancore and Madras from May to Augut. When feeding on teak the young hoppers collect in colonies of several scores of individuals on plants of moderate height, particularly seedlings, coppice-shoots and saplings; they do not appear to ascend to the crowns of trees. A plant may be completely denuded of foliage by a colony which commences with the youngest and uppermost leaves and gradually works downwards. When the hoppers are young the work of this species resembles skeletonisation by *Hapalia machaeralis* or *Diacrisia obliqua confusa* or the coarser perforation of *Hyblaea puera*; the older hoppers eat the whole of the leaf-blade except the tip and the midrib and stouter veins. The adults when singly or in small numbers produce large holes and ragged emarginations; in the imaginal stage feeding is at a slower rate and although the imaginal life is prolonged the

individual adult does relatively less damage than the hopper.

Recording an outbreak in Travancore, Jones, 1940, says "The grasshoppers seldom came to earth except by accident and hence none of the ground crops were affected. Their preference for teak leaf was remarkable and it was not unusual to see the branches of this tree bent down by the weight of the pest. Every leaf had on an average from 20 to 30 insects and due to their protective colouration it was hard to detect their presence except for the chirruping noise they made and the continuous fall of the faecal pellets".

Swampy land or areas liable to waterlogging, provided there is a fair amount of shade, appear to be most liable to invasion by *Aularches miliaris.* Dry teak areas and well lighted stands are free from this pest. Its importance arises from the fact that it occurs mainly at a period (May to August), when the caterpillar defoliators are scarce and when the teak is recovering from the pre-monsoon attack of *puera* and *machaeralis.*

Eggs are laid in a mass of 50 to 115 in a hole about 3 inches deep in the soil of moist localities at the close of the monsoon, October–December. The eggs hatch after about 5 months, mainly in April, and the adult grasshoppers appear from June onwards living until November-December. The generation is thus annual. The adult is 2 to 2½ inches long with a yellow and black tuberculate thorax, black and red transversely striped abdomen and blackish-green forewings with white or yellow spots.

Hutson J. C., 1935, *Trop. Agr.*, LXXXV, pp. 127-129, 1 col. pl., 7 figs.
— 1926, *Year Book Dept. Agr. Ceylon*, pp. 36-44, The spotted locust (Aularches miliaris)
Jones S., 1940, *Journ. Bomb. Nat. Hist. Soc.*, XLI, 3, pp. 676-678, figs.

Catantops humilis, C. innotabile and **C. pinguis** are other species that feed on *Tectona grandis* in India and Burma. **C. indicus** is injurious to seedlings of *Pinus longifolia.* **C. splendens** defoliates stump-plants of *Tectona grandis.*

Ceracris deflorata and **Chlorizenia unicolor** feed on *Tectona grandis.*

Choroedocus illustris defoliates and decorticates young plants of *Morus indica.* **C. robusta** feeds on *Tectona grandis.*

Species of the genus **Chrotogonus** are small earth-coloured short-winged grasshoppers injurious to the germinating seedlings of trees in nurseries and regeneration areas, especially to *Anogeissus latifolia, Dalbergia sissoo, Cedrus deodara, Pinus* spp., and *Shorea robusta* in north India. The eggs are laid in clusters in holes in the soil and hatch in 2–3 weeks; nymphal development continues for 8–10 weeks. There are 2 generations in north India starting in April and in September.

Dittopternis venusta feeds on foliage of *Tectona grandis.*

Epistaurus sinetyi, Eucoptera saturata and **Euprepocnemis alacris** feed on *Tectona grandis* foliage.

Hieroglyphus banian is a green or dry grass coloured acridid, 1–2 inches long, with incised black lines on the prothorax and the

hind tibiae blue. The tough egg-masses (7 to 30 eggs) are laid in the soil or on the surface under dead leaves and grass in the last 3 or 4 months of the year and remain unhatched until the rains of the following year have set in. The young hoppers are brownish-yellow with a yellow stripe on the thorax. They feed for 10 to 12 weeks, June to September, before becoming adult. The life-cycle is annual. The species is a defoliator of bamboo forests (*Dendrocalamus strictus*). It is also a major pest of rice, maize, and sugarcane, and feeds on wild grasses. An outbreak of this species occured in Hoshiarpur forest division in 1933 and 1934 and the hoppers invaded neighbouring cultivated lands but were killed off by an epidemic at the end of August.

Coleman L. and Kunhikannan K. 1912, *Mysore Dept. Agr., Ent. Bull.*, No. 1, The rice grasshopper.
Main, *Agric. Journ. India*, VII, p. 246, Campaigns against the rice grasshopper
Ramakrishna Ayyar T. V., 1933, *Agr. and Livestock in India*, III, p. 345, pl. xx, figs. 1-3, pl. xxiv, xxv (control on rice in Madras).

Locusta migratoria, The Migratory Locust. This true locust is a serious pest in Europe, Africa and Eastern Asia; it occurs in the desert areas of Sind, Baluchistan and Rajputana. Its solitary phases are capable of long distance migration like those of *Schistocerca peregrina* and are found throughout India but it differs in its ecological preferences, favouring a fairly moist environment and foodplants of the grass families. These preferences are of special significance as they lead to the formation of concentrations on irrigated crops like wheat and millets in hill valleys and to the development of outbreak centres in such places as the result of crowded breeding. Although the solitary phase of *Locusta migratoria* occurs throughout India there are no definite records of swarms except in Baluchistan, Kathiawar and Gujarat in 1937 and in south and south-eastern Madras in 1878, which seems to have been due to the failure of the rains in 1876 (which was the year of the great South Indian famine) and the heavy rains of 1877. A serious infestation is not likely to develop except as a result of unusually high rainfall in winter as well as in summer.

Rao Y. R. and Bhatia D., 1936, *Ind. Journ. Agr. Sci.*, IX, pp. 79-107, pl. 1, map, On the probability of seasonal migration among the solitary phase individuals of Locusta migratoria in north west India.
Rao Y. R., 1940, *Proc. 27th Ind. Sci. Congress*, III, p. 180, A preliminary note on some of the locust invasions of the past in Madras Presidency.

Oedalus abruptus, a very common grasshopper, and **Oxya velox** are sometimes injurious to seed-beds and sowings of *Pinus longifolia*, *Shorea robusta*, etc. The latter species is a pest of rice, sugarcane, pulses, etc., it breeds throughout the year occurring in greatest numbers in the rainy season.

Pachyacris venosa feeds on *Tectona grandis* foliage.

Patanga succincta, The Bombay Locust. This locust occurs in small numbers in most of the wetter forested regions and

throughout the plains of India, but it breeds most abundantly in the forests of the moist elevated regions in Kanara, Goa and the Western Ghats. There is only one generation per annum. Eggs are laid in damp soil in clusters at the beginning of the rains, i.e., June–July; they hatch in 5 or 6 weeks. The hoppers occur throughout August and September and do not collect into armies in order to feed but behave like ordinary grasshoppers. After 7 moults, which are passed through in 6 weeks, winged locusts appear in late September, and live for about 8 months. There are several definite phases in the migration of the species. The young locusts, which emerge in the breeding-grounds at the end of September, begin to migrate in swarms at the end of October. Flights take place mainly on moonlit nights but also by day. The winter (November to March) is spent in the hill forests between Bombay and Goa. During the cold nights the locusts are torpid, and do not move until warmed by the sun. A second migration takes place in March until the end of May which carries the swarms to the north-east, east and southeast over the region embracing Gujarat, west Central India, west Central Provinces, Berar, northwest Hyderabad and Madras. Towards the end of May the swarms break up and scatter, egg-laying taking place in June with the coming of the monsoon and the locusts then die.

The adult *Patanga succincta* is about 2–3 inches long of a general brownish colour, the thorax marked with alternate longitudinal bands of yellow and dark colour and the wings marked with more or less broken lines of light and dark colour. The colour phase of the swarming locust is a vivid red; after the swarms break up and reproduction occurs the red coloration gives place to the brownish, or wet ground colour. A large outbreak of the Bombay Locust occurred in Madras in 1865, and 1879 to 1884 and in Bombay in 1901–1908.

Poecilocerus pictus is a strikingly coloured grasshopper with lines and stripes of bright bluish-green and yellow, feeding chiefly on *Calotropis gigantea* and *C. procera* but occasionally responsible for heavy defoliation of bamboo forests in dry regions and the destruction of seedlings of *Pinus longifolia*. It is also a pest of cultivated plants and vegetables. There is normally one generation in the year with hibernation in the egg-stage. Eggs are laid in masses of 100 or so in the soil from June to August. A small portion of the brood hatches in 7 or 8 weeks and the remainder does not hatch until the following spring. The early brood passes the winter in the nymphal stage; there are 7–9 moults before the adult stage is reached in the spring. The eggs that overwinter give rise to adults 7 to 9 weeks after they hatch; there are 5–7 nymphal stages. The biology and control is given by Pruthi, 1939, *Ind. Journ. Agr. Sci.*, IX, pp. 629–642, pls. xxix, xxx, coloured.

Quiroguesia blanchardiana and **Spathosternum prasiniferum**

(the latter is one of the commonest grasshoppers in India) damage young seedlings of *Pinus longifolia*, eating first the apical whorl of needles and then biting through the stem. The latter also feeds on *Tectona grandis* trees and coppice-shoots in India and Burma.

Schistocerca gregaria, The Desert Locust

Life-history: **The solitary phase**: The permanent home of the solitary phase of the Desert or North west Locust is among the scanty vegetation of the desert regions in north Africa, Arabia, Persia, Baluchistan, Sind, Kathiawar, Rajputana and the north-west Punjab. There are 2 generations of about equal length each year, the first breeding in the western winter rain areas and the second in the monsoon area of the Indian desert; migration from one area to the other occurs at the change of the seasons. In Mekran and southern Sind-Rajputana the overwintered females begin to lay eggs in February if there have been good winter rains, and continue to lay and to migrate to the hill-valleys during March and April. The eggs are deposited in clusters up to a total of about 300, usually concentrated in colonies in dry sandy soils. Hatching takes place in 3 or 4 weeks and the hoppers, passing through 6 or 7 moults, become mature in 6 or 7 weeks. Adults of this generation are ready for flight by April in the south and by May or June further north; they live for about 5 months. The eggs of the second generation are laid when the monsoon rains begin in July and further batches are laid if good rains occur in August and September. The first summer broods of hoppers are mature by September and these locusts may lay eggs for a third generation in September, October. Many of these early adults and those of later monsoon broods survive through the autumn and winter. In its permanent breeding-grounds the number of generations produced by the solitary phase depends on the sequence of rainy periods. If rains follow in quick succession breeding is extended and the locust population may increase sufficiently to cause the formation of the gregarious phase and the migration in swarms. There is no diapause in *S. gregaria* in any stage of its development.

The gregarious phase: Periodicity of epidemics: Between 1860 and 1940 seven cycles of infestation have occurred in India. Recent appearances of the Desert Locust over northern India were in 1900–1907, in 1912–1919 and in 1926–1931. Each period of infestation lasts 5–9 years with free intervals varying from 1–4 years (but in some cases extending to 8 years). Heavy winter rainfall followed by heavy and well-distributed monsoon rainfall are the main factors in the production of epidemics. Such was the case in 1940, 1926, 1911–12 and 1900.

The locust-cycle is as follows: During periods between epidemics solitary locusts exist in the scrub vegetation of the semi-desert habitat. They migrate in early summer into the

summer-rain areas of the Rajputana desert where breeding takes place during the monsoon. This generation migrates in autumn to the winter-rain areas where breeding occurs in the spring of the following year. The activities of the swarms thus show 3 stages:—i, Over-wintering of scattered swarms takes place in the warmer areas (south Mekran, Sind and south Punjab). ii, Spring-breeding and movement of swarms northwards to Baluchistan, the Punjab and western United Provinces ensue wherever good winter rainfall has occurred. The swarms may be so dense and extensive that the light of the sun is obscured. This is followed by migration in May, June during the period of summer drought on the prevailing winds eastwards into Punjab, Sind, Rajputana, Central India, Bihar and Bengal, sometimes travelling as far as Assam and into the inner valleys of the Himalayas, which the swarms reach during June and July in successive waves of migration. iii, Summer-breeding with the onset of the monsoon rains. All swarms which are gradually shifting westwards settle and lay eggs and, as with the solitary phase, 2 or even 3 batches of eggs are laid if the weather continues favourable.

With the cessation of the monsoon, the Rajputana desert and the plains of north-west India become dry torrid areas which are forsaken by the swarms residing in them. These locusts migrate with the changing winds east, south and west to their homelands in Kathiwar, Baluchistan and Iran where they are able to breed again in the following spring and their offspring renew the invasion of the Indian provinces in the summer. On the other hand the swarms that have reached Bengal, Central India and Bombay are unable to breed and gradually die off.

The ability of swarms in a particular year to return westwards in autumn and winter determines the incidence with which the following year will be started. If the winter rainfall in the west or the monsoon in the east fails there is a reduction in the number and size of the swarms and a complete breakdown may result. The epidemic comes to an end and the cycle is completed.

The adult *S. gregaria* is $2\frac{1}{2}$ to 3 inches long, of a uniform yellow, pink, or purplish colour, spotted with black on the body and wings; there are no longitudinal bands or lines of colour. Early in their lives the locusts are pink with a purplish tinge; this colour phase lasts for about 2 months and is characteristic of the migrating swarms. Prior to reproduction the locusts turn bright yellow, a colour characteristic of the egg-laying period.

Economic importance: Primarily an agricultural pest this locust is injurious to young regeneration and sowings in forest divisions of the North-west Frontier Provinces, the Punjab and Sind and in the hill regions and afforestation divisions in the United Provinces. In jungle land *Acacia modesta*, *Capparis aphylla*, *Casuarina* and *Olea cuspidata* suffer considerably, while *Acacia arabica*, *A. jacquemontii*, *Prosopis spicigera*, *Salvadora*

persica and *Tamarix* are relatively little damaged. *Azadirachta indica* and *Calotropis gigantea* are avoided and are actually poisonous to the hoppers and locusts. The preferred food-plant of the solitary phase is *Heliotropium ramosissimum*.

LITERATURE :

Bhatia D. R., 1940, *Ind. Journ. Ent*, II, pp. 187-191, Foodplants of Schistocerca gregaria.

Husain M. A. and Taskhir Ahmad, 1936, *Ind. Journ. Agr. Sci.*, VI, pp. 188-261, figs, Studies on Schistocerca gregaria.

Karandikar K. R, 1933, *Ind Journ. Agr. Sci.*, III, pp. 847-850, pl. lxvii, Breeding grounds of the Desert Locust in Baluchistan.

Ramachandra Rao Y., 1933, *Ind Journ. Agr. Sci.*, III, pp. 833-846, pl. lxv, lxvi and 2 maps, Mekran possibly the country of origin of the great locust invasion of Sind in 1926.

Ramachandra Rao Y, 1941, *Proc. 28th Ind. Sci. Congr.*, Pres. Address, Ent, Some observations on the periodicity of locust invasions in India (Summary in *Ind Journ Ent*, II, pp. 193-199).

Spathosternum prasiniferum feeds on foliage of *Tectona grandis*.

Teratodes monticollis is a green or dry-grass coloured insect with the prothorax flattened into a high curved ridge over the body. It is injurious in seed-beds and patches of new regeneration and also as a defoliator of large trees. One individual can eat a whole teak-leaf in a day leaving only the lower part of the midrib.

Thisoicetrus pulcher defoliates and decorticates young plants of *Morus indica*.

BLATTIDAE

COCKROACHES occur abundantly in the soil-covering, among decaying leaves, in organic refuse and also on flowers and vegetation. They are on the whole scavengers feeding on dead animal matter, fermented sap, etc. but some forms are definitely predaceous on small living insects. For one or the other of these reasons cockroaches are often found at wounds made by other insects in the bark or wood or seeds of trees, where they are likely to be mistaken for the real causes of the damage. Domesticated species occur in houses, bazar shops, etc., feeding on a great variety of substances including provisions, especially sweetened, starchy and oily matter, beeswax, paper, the leather and cloth of books, shoes. They spoil more human food by contamination and bad odour than they actually eat. The eggs of Blattidae are laid in horny bag-like oothecae. The ootheca is formed in the genital pouch of the female and the eggs are added to it gradually; so that it is carried about projecting from the end of the body of the female for some time before and after it is completed; eventually it is deposited in a place suitable for the hatching of the young cockroaches, which thereafter live an independent life.

LITERATURE ON BLATTIDAE :

Chopard L. and Chatterjee N. C., 1937, *Ind. For. Rec.*, Ent., III, No. 1., pp. 5-9, Blattidae of sandal (31).

Periplaneta americana is the commonest house cockroach throughout India and was originally native in subtropical and tropical America whence it has become cosmopolitan. It is omnivorous eating paper, books, leather and cloth-bindings, especially where paste or sizing is used, boots, hair, starchy, fatty, floury and sugary food-substances in kitchens and storerooms, dead and living defenceless insects, their own cast skins and oothecae, etc. Water is essential. Cockroaches contaminate human food by leaving their excreta on food and on vessels and by infecting it with pathogenic organisims carried on the legs and bodies. An unpleasant roachy odour is also imparted. Moist air, warmth and darkness form the most favourable environment.

Life-cycle: Eggs are collected in a capsule or ootheca, which is formed gradually within the cavity at the end of the abdomen and gradually protruded. Females carry the maturing ootheca visibly protruding for several hours up to 24; they are deposited in sheltered places stuck down with an adhesive and concealed with particles of rubbish. Eggs are produced mainly in the hot months from April or May to October. Both nymphs and adults become dormant in the coldest season. Repetition of egg-laying depends on access to males and may take place at weekly intervals on the average. The ootheca of *P. americana* is a hard dark brown bean or purse-shaped object about 8 mm. long and contains about 16 eggs. In N. America the ootheca may contain 18 to 24 eggs which hatch in 27 to 30 days.

The number of nymphal instars is variable from 7 to 9—their duration is also variable, the earlier instars lasting a shorter time than the later instars. In the cold season there is a marked prolongation of the nymphal stage during hibernation. The development of the insect is slow and varies with food-supply and the temperature of its environment. The adult stage may be reached in 10 months or may require 21 months. For practical purposes the common house cockroach may be regarded as having an annual life-cycle in India with adults in March–October. The relative abundance of adults and of young instars gives some indication of the extent to which breeding is taking place inside a house or of the extent of infestation from outside. For control see Part Two.

Nigam L.N., 1933, *Ind. Journ. Agric. Sci.*, II, pp. 530-543, pl. xxxv–xxxviii. The life-history of the common cockroach (Periplaneta americana Linnaeus).

Periplaneta australasiae occurs as a house cockroach mainly in South India and Ceylon. It greatly resembles *P. americana* but is distinguished by the presence of two yellow streaks on the costal margin of the forewings running obliquely from the hind margin of the pronotum.

GRYLLACRIDAE

COMBINING the characters of the Gryllidae and the Tetigoniidae *this family consists of forms that are mostly predators on* living insects.

Schizodactylus monstruosus is a somewhat abnormal gryllacrid having long forewings which roll up from the tips in a spiral and are bent at right angles near the bases as in the Gryllidae. The female has no ovipositor. The tarsal joints are lobed at the sides. It is a burrowing species living in the plains of India in sandy soil and alluvium in which the eggs are laid and the young forms develop. Mainly carnivorous it is destructive to crops when it cuts through the roots of plants met in the line of its burrows; in this way it is injurious to 5 months old *Tectona grandis*. The species is replaced in Burma by **Schizodactylus burmanus.**

GRYLLIDAE

GRYLLIDAE are Crickets, under which term is included the ground and house-crickets, plant-crickets, mole-crickets and *small surface forms. Most Gryllidae lay their eggs* and live either in the soil in tunnels, (which in some forms are deep and permanently occupied and in others are temporary surface-shelters), or among dead leaves and debris on the surface of the ground. On the whole they are herbivorous, some being injurious to seedlings in nurseries and sowings in the open, e.g., *Brachytrypes* which cuts off young seedlings or low shoots at night and drags the pieces to the tunnels for feeding, or *Gryllotalpa* and *Tridactyla* which also uproot or bury seedlings by burrowing just beneath the surface of the ground. Together with grasshoppers and cutworms and cockchafer grubs they form the chief pests of young seedlings, but are rarely detected in the act of injury. Some species feed on dead insects and on animal remains and some are considered to be predaceous. The tree-crickets (*Oecanthus*) lay their eggs in the shoots of plants in the same way as do the longhorned grasshoppers (Tettigoniidae). This form of injury on thin branches of *Shorea robusta* causes a thickening and stunting of the growth followed by the rotting of the wood.

LITERATURE ON GRYLLIDAE:

Chopard L., 1928, *Spol. Zeyl.*, XIV, pp. 197-208, Additional notes on the Gryllidae of Ceylon.

— 1928, *Rec. Ind. Mus.*, XXX, pp. 1-36, Revision of Indian Gryllidae.

— 1936, *Spol. Zeyl.*, XX, pp. 9-87, The Tridactylinae and Gryllidae of Ceylon.

Chopard L. and Chatterjee N. C., 1937, *Ind. For. Rec.*, Ent., III, No. 1, p. 19, Gryllidae of sandal (31).

Brachytrypes portentosus. This large blackish-brown cricket, 2 inches long, [fig. 186] makes a deep tunnel which opens at the surface of the ground in a large conspicuous hole surrounded by ejected earth. The eggs are laid at the bottom of the tunnel in September–October and the newly hatched larvae remain for

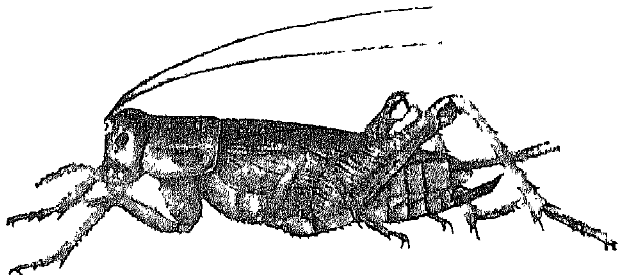

Fig. 186. **Brachytrypes portentosus, natural size $1\frac{3}{4}$-2 ins.**

some time in the maternal home and then disperse. Young crickets dig themselves new tunnels every few days and the tunnels are longer and more ramified as the insects grow older. The adult stage is reached in a few months by about May–July and the rest of the year is passed in this form and the same tunnel is usually occupied throughout. The cricket feeds on young seedlings and low shoots cutting them off at night and dragging the pieces into the tunnel for feeding. The greatest damage is done in March–April and September. It is injurious in nurseries of *Casuarina equisetifolia*, *Dalbergia sissoo*, *Eucalyptus*, *Ficus elastica*, *Hevea brasiliensis*, *Tectona grandis*, tea and to agricultural crops. Transplants of *Casuarina* less than 2 feet high are liable to attack and those over 4 feet high escape. In Burma and the Chittagong Hill Tracts this cricket is collected for food and eaten roasted or fried in oil.

Andrewes E. A., 1922, *Qr. Journ. Ind. Tea Assoc.*, III, p. 112. A note on crickets.

Ghosh C. C., 1912, *Mem. Dept. Agr. Ind.*, Ent. IV, No. 3, pp. 161-182, The big brown cricket.

Iyer V. S., 1912, *For. Bull.* No. 11, pl. III, figs I, a, b, Casuarina insect pests of Madras.

Brachytrypes orientalis is injurious to seedlings in a similar manner, e. g., *Xylia dolabriformis*.

Gymnogryllus erythrocephala and **G. humeralis** damage seedlings of *Casuarina equisetifolia*, *Dalbergia sissoo* and *Eucalyptus* spp.

Gryllodes sigillatus is the common house-cricket feeding on refuse particularly greasy and fatty matter and is also injurious to paper, cloth and leather bindings of books, and clothing. It has also been found as a pest in nurseries of tree seedlings (for control measures see Part Two.)

Gryllotalpa africana, The Mole Cricket, is a light brown insect about $1\frac{1}{4}$ inches long. It is essentially subterranean, seldom leaving the burrow except at night. It is most abundant in light loamy and alluvial soils and easily compressible earth in which tunnelling is easy and avoids dry localities. The special modifica-

tions for burrowing affect the pronotum which is a hard rounded shield, and the forelegs which have the coxae and femora thickened, and the tibiae and tarsal segments which are produced so as to form sharp scissor-like cutting and scraping organs. The mole-cricket feeds primarily on plants and rarely on animal matter preferring young seedlings and small growth, which are gnawed through at the collar, or bitten-off leaves; sometimes the plant is pulled into the soil-burrow while feeding. Damage is done to plants not acceptable as food by the removal of roots, etc., obstructing the burrows or by burying or dislodging germinating seedlings.

Life-cycle: The winter is passed underground in the nymphal stage; it becomes active again in spring and adult in May–June. The female prepares an earthen cell about as big as a hen's egg with smooth hardened walls located at the end of a tunnel a few inches below the surface of the ground. Eggs are laid in a cluster of up to 50 and are watched with unusual maternal solicitude during the 3 or 4 weeks required for hatching. The young crickets remain together for a few weeks in the company of the mother and then disperse. After 3 or 4 moults they go to deeper levels in the soil for hibernation. The life-cycle is a year with 8 moults; in warmer regions there are possibly 2, or more, generations per annum.

Seedlings of *Bischofia javanica* and *Cinnamomum cecidodaphne* in nurseries in Bengal are recorded as damaged by mole-crickets. Sowings of *Cedrus deodara* in ash-beds in Kashmir are regularly damaged by the burrowing of *G. africana*.

Gryllulus domesticus, The Black-headed Cricket, is an omnivorous species and a pest of various crops in the dry region of the western frontiers of India and in Baluchistan. Sown seeds are eaten; germinating seedlings are cut off level with the ground and the cotyledons are eaten; the leaves of older plants are bitten up. When fresh vegetable matter is scarce, dry organic matter is eaten such as human food, clothes and animal carcasses.

Life-cycle: Eggs are laid in cracks in dry and barren soil in or about September and remain unhatched until March. The cricket nymphs become full-grown in about 3 months, i.e., in June but the adults do not generally pair until September. The females die after ovipositing but a few survive till late in winter. During the period of activity April to July the crickets inhabit cracks and shelters in the soil during daytime, emerging during the night and usually working together in swarms till daybreak. A large swarm has been observed to cover an area of one furlong by 100 yards; its passage is accompanied by a noise resembling the murmur of a river in flood. The adult is about 2·7 cm. long and although winged does not take to flight. For control measures see Part Two, Gryllidae.

Janjua N. A., 1939, *Agr. and Livestock in India*, IX, pp. 688-694, figs. 1-3.

Species of **Tridactylus** are very small crickets ¼ to 3/8ths of an inch long with very short antennae and no tarsi on the hind legs but instead a pair of straight processes. They live in damp ground, e.g., banks of tanks and ponds, in irrigated fields and seed beds and burrow in tunnels just below the surface throwing out the soil in heaps that may bury small germinating seedlings. They are injurious in nurseries of, e.g., *Tamarix articulata*.

LOCUSTIDAE see TETTIGONIIDAE

MANTIDAE

PRAYING or Preying Insects are exclusively carnivorous. In all stages the front legs are adapted for seizing and retaining the prey, which consists of other insects of all orders. Each forecoxa is almost as long as the femur; the tibia closes into a groove on the ventral edge of the femur after the manner of the blade of a pocket-knife but the opposed edges of both segments are furnished with sharp teeth. The other 2 pairs of legs are of the normal walking type. Young nymphs are active, running about with the abdomen cocked up [fig. 188], except in species of *Deiphobe* in which it is held horizontally. The raptorial legs of *Creoboter* and *Hierodula* are held closely flexed against the prosternum, while *Deiphobe* extends them forwards and flexes them just before striking at the prey. Adults usually sit motionless in wait for approaching prey and are concealed from detection by their resemblance in colour and form to the background of foliage or bark or dead leaves.

There is a great variety in the food of the Mantidae. The newly emerged nymphs feed on minute insects, such as chloropid flies and plant lice, while the adults of the large species of *Hierodula* are reputed to be able to kill sunbirds. Preserved in the museum of the Bombay Natural History Society is a specimen of *Hierodula ventralis* which struck at a sunbird hovering near and completely scalped it, the blow also killing the bird. The mantids "form part of that very valuable section of insectivorous animals which feed on any insect that becomes abundant: like the birds they eat whatever insect is available; and this is a most useful group in checking the periodical wave-increase of insects, which are only pests when in great abundance." (Lefroy). The sandal tree, for example, is regularly frequented by 15 species of Mantidae.

The eggs are laid in hundreds in a frothy gum which hardens into large globular or elongate masses (*ootheca*) attached to twigs or grass, etc. [fig. 187] from which the nymphs hatch in about 3 or 4 weeks. The life cycle is annual, or in 2 generations a year.

LITERATURE ON MANTIDAE:

Chatterjee N. C., 1937, *Ind. For. Rec.*, Ent., III, No. 1, pp. 10-14, Mantidae of sandal (31).

Henry G. M., 1931, *Spol. Zeyl.*, XVI, pp. 123-128, New Ceylonese Mantidae.

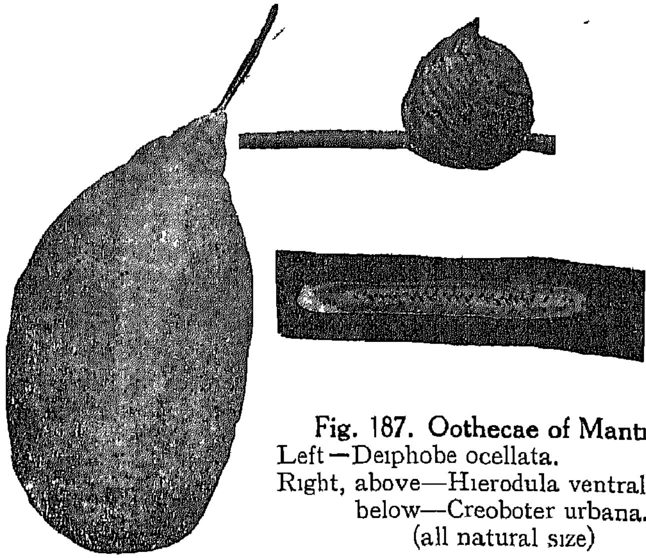

Fig. 187. Oothecae of Mantidae.
Left—Deiphobe ocellata.
Right, above—Hierodula ventralis.
below—Creoboter urbana.
(all natural size)

— 1932, *Ind ent*, XVII, pp 1-18, Observations on some Ceylonese Mantidae.
Mathur R N, 1934, *Ind. For Rec*, Ent, XX, iii, pp 26, pl 1, On the biology of the Mantidae (with notes by Beeson and S N. Chatterjee)

Aethalochroa ashmoliana. The adult is elongate, dark brown, with slight expansions on the legs, length 4½ inches; the nymph is coloured and patterned to resemble bark and is about 3¼ inches long when full grown in September. It feeds on caterpillars and moths of *Hapalia machaeralis, Plecoptera reflexa* and *Catopsilia crocale.*

Creoboter urbana, a small pale green mantis with a round yellow "eye spot" ringed and centered with black on each tegmen, length 1½ inches, feeds as nymph and adult on caterpillars and moths of *Hapalia machaeralis, Hyblaea puera* (defoliators of teak), *Nephopteryx rhodobasalis* (defoliator of *Cassia fistula*), *Plecoptera reflexa* (defoliator of *Dalbergia sissoo*), also of *Euphaleinus vittatus, Phylloplecta* sp, *Trioza fletcheri minor* (Psyllidae) The nymphs eat small caterpillars at the rate of about one caterpillar per day during the later stages, and the adults take a caterpillar or moth every other day.

The ootheca [fig 187] is elongate, convex, about 30 mm. × 5 mm, light brown, attached by its flat base to a leaf, it contains about 80–160 egg cells in 4 rows on both sides of the median line. Each pair of egg cells opens into common vestibule protected by a small thin flexible flap, thus showing on its dorsal surface half as many slits as there are eggs. These hatch in 3 or 4 weeks.

The young nymph is dark brown with black markings and holds the abdomen raised nearly vertically. The 3rd stage nymph is banded in brown, yellow and black, variegated with green. *C. urbana* moults 7 or 8 times. The nymphal stage lasts 60 to 90 days in the monsoon-season, adults appearing in October from eggs laid in June; they live for about 2 months. There are 2 generations a year in north India.

Dysaules himalayanus is brownish with transparent tegmina scarcely visibly marked; the prothorax is elongate and the head is concave between the eyes; length 2 inches. It occurs in the early part of the monsoon and feeds on caterpillars of *Hapalia machaeralis* at the rate of 2 per day.

Deiphobe incisa has habits similar to those of *ocellata* and is a particular enemy of *Plecoptera reflexa*. Ootheca and nymphs were utilised in 1938 and 1939 to colonise the species in some of the irrigated plantations in the Punjab.

Deiphobe ocellata. The adult is dark brown, with a large yellow spot near the apex of the hindwing; length 3½ to 4 inches. The ootheca [fig. 187] is a large globular frothy mass, 40–60 mm. × 20–30 mm., creamy to bluish-green in colour, and terminating at one end in a thin filament. It may be attached to a grass stem or a broad surface. A female takes 3 to 4½ hours to complete the construction of an ootheca and may lay altogether 5 at intervals of 10–15 days, each of which contains 200 to 400 eggs; these hatch in 2 to 3 weeks in July–August. The young nymph is fawn, spotted with dark brown; 3 chocolate brown stripes develop on the dorsal surface in later stages. There are 9 or 10 moults during a nymphal life of 315 to 330 days; the adults appear in June and live for 50 to 100 days. The life-cycle is annual in north India. It feeds on caterpillars, moths and flies generally.

Euantissa pulchra feeds on nymphs of *Petalocephala* and other Jassidae.

Hestiasula brunneriana has greyish-green wings with inconspicuous spots and pale brown forelegs of which the femora are greatly expanded; length 1 inch. It is adult in September and feeds on *Hyblaea puera* caterpillars.

Hierodula ventralis. The adult is dry green or pale green without conspicuous markings except for a small glossy streak near the middle of the tegmen; the prothorax is not widened by a lateral flange; length nearly 3 inches.

Life-history: The ootheca is more or less oval, 18–24 mm. by 16–19 mm., light brown, containing about 190 to 360 eggs [fig. 187]. The female takes about 2½ hours to construct an ootheca. The eggs hatch in 21–25 days in July–September. Those laid in November overwinter for 5 months in north India. The young nymph is pale green with banded legs; in the 4th stage it is purplish green and a dark band along the middle of the back [fig. 188]. There are 8 or 9 moults. The nymphal period is

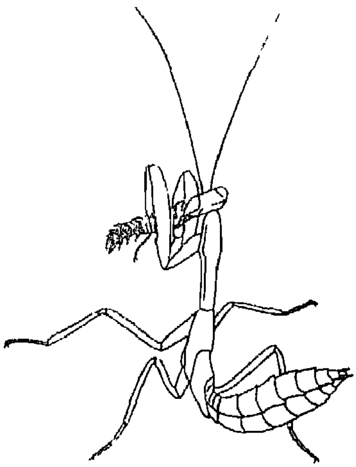

Fig. 188. Nymph of Hierodula ventralis in feeding-attitude. (natural size).

70 to 110 days in July to October. There are 2 generations a year in north India, the adults of the 1st generation appearing in May-June and producing a brood that may mature in about 3 months. The adults of the 2nd generation occur from September to November and give rise to a brood of slower development, about 280 days, passing the cold weather and early hot weather in the last three nymphal stages. The adult lives about 100 days. This species feeds on various caterpillars and moths including the teak defoliators, *Hapalia machaeralis* and *Hyblaea puera* and *Ethmia systematica* (Yponomeutidae), *Hypsipyla robusta*, *Nephopteryx rhodobasalis*, *Pieris brassicae*, *Plecoptera reflexa*, *Pyrausta coclesalis*, Geometridae, Muscidae, Psyllidae, etc. The young nymph eats at an average rate of 0·6 to 1·0 insect per day and in the last two nymphal stages eats about 1·5 caterpillars a day. The adult mantis eats about one insect per day.

Mathur R. N., 1934, *tit. cit.*, pp. 14-21, figs. 3, 5, 8, 10 (Hierodula westwoodi).

Oxyophthalmus gracilis feeds on nymphs of *Ledra*, *Petalocephala* and other Jassidae.

Rhombodera tectiformis. The adult is pale green or dry grass coloured without markings except for a small glossy streak near the middle of the tegmen; the prothorax is nearly as wide as long owing to the development of a broad flange; length 3 inches and over. It feeds on various caterpillars and moths including teak, shisham and amaltas defoliators. The adult hibernates in north India living for about 5 months.

PHASMIDAE

STICK and Leaf Insects typically inhabit moist tropical forests in the Indian region but although entirely herbivorous and

voracious feeders they rarely occur in large numbers and hence are not known as pests. Some species occur in the arid regions of northwest India.

The leaf insects have the body flattened and the legs provided with flat membraneous expansions and the wings coloured and veined to resemble leaves green or withered; other species resemble fragments of dead leaf, lichens or pieces of bark. The stick insects are long rod-like forms usually wingless and coloured green or light brown like stems of fresh and dry grass or mottled like twigs and sticks; the body of a large individual is 8 inches long. Eggs of some species are cemented in rows to sheltered surfaces; of others are dropped broadcast. They hatch in about a month. The life-cycle of **Phyllium scythe** takes about 16 months; other species are complete in 4 months.

Gunther K., 1938, *Rec. Ind. Mus.*, XL, pp. 123-141, Neue und wenig bekannte Phasmiden aus dem Indian Museum.

Aiyer T. V. R., 1913, *Journ. Bomb. Nat. Hist. Soc.*, XXII, pp. 641-643, pl., The life-history of a phasmid.

TETTIGONIIDAE

LONGHORNED Grasshoppers (distinct from the Acrididae by their longer antennae) are in many species formed and coloured to resemble leaves, bark, etc. and of large size (3 or 4 inches); a few species mimic ants (Formicidae) or Cerambycidae. Sometimes eggs are laid with the very long and sword-like ovipositor in the soil but they are usually deposited in rows in slits cut in the epidermis of a twig or soft shoot or in the edge in a leaf. These slits do not heal readily after the escape of the young larvae and cause the dying-back or breaking-off of the twig. Some forms are herbivorous but none are sufficiently abundant to be known as pests, possibly because most of the feeding is done at night and is restricted to the perforation and ragging of leaves. Other species are carnivorous or burrow in the soil. They are most abundant in the rainy season.

LITERATURE ON TETTIGONIIDAE:

Chopard L. and Chatterjee N. C., 1937, *Ind. For. Rec.*, Ent., III, No. 1, pp. 19, Tettigoniidae of Sandal (31).

Henry G. M., 1932, *Spol. Zeyl.*, XVI-XXI, Systematic papers on Ceylonese Tettigoniidae.

Letana inflata feeds as nymph and adult on the foliage of *Santalum album*. Eggs are laid in longitudinal slits in succulent shoots and stems of young saplings and seedlings. From 9–15 dark, doubly convex eggs are deposited in a row in each slit and hatch in about a fortnight. The nymph moults 6 times in the course of 4½ months. There are 2 generations a year in south India, with maximum abundance of adults in December–February. In shoots of sandal of over finger-thickness the oviposition-slit leaves a scar of dead bark ¼ to ¾ of an inch long; in seedlings and small stems the slit swells and cracks laterally.

Mecopoda elongata eats teak leaves amongst its varied food-supply.

Sathrophyllia rugosa eats the young shoots and leaves of *Butea frondosa*. The adult, 3 inches long, is remarkable for its cryptic coloration which completely conceals it when resting on lichen-covered bark.

RHYNCHOTA

MODERN taxonomy separates the Order RYHNCHOTA into two groups Hemiptera (or Heteroptera) and Homoptera with ordinal rank. For the needs of forest entomology it is convenient to class all the sap-suckers and bugs together in order to emphasise ecological similarities. The chief morphological differences are that the Hemiptera have the forewings thickened and stiff in the basal half and thin or membranous in the distal half; at rest the wings lie horizontally with the distal parts of the forewings overlapping. The Homoptera have both pairs of wings uniformly membranous or slightly leathery; at rest they are held obliquely meeting at an angle along the mid-dorsal line with the tips only slightly overlapping [fig 189]; many forms are wingless. Rhynchotous mouth-parts are variously constructed for the purpose of piercing plant-tissues and sucking sap; in some predaceous bugs (Pentatomidae Reduviidae) the beak serves to suck up other liquids including the body-fluids of insect prey or (Cimicidae) the blood of mammals. The feeding-habits of the nymphs are usually the same as those of the adults. From this biological aspect the more important families may be grouped thus:—

Sap suckers

Scale insects and Mealy bugs—Coccidae
Whiteflies and Greenflies—Aleyrodidae, Aphidae
Plant-hoppers, Cicadas, etc.—Cercopidae, Cicadidae
Coreidae, Fulgoridae, Jassidae, Membracidae,
Pentatomidae, Psyllidae, Tingitidae.

Predaceous Bugs

Terrestrial predators—Capsidae, Pentatomidae,
Reduviidae
Aquatic predators—several families

Blood-suckers Cimicidae

S a p - s u c k e r s: Bugs which feed on the sap of the succulent stems, leaves, flowers or fruits of trees normally attack the perfectly healthy tree, but many species thrive better and multiply on an unhealthy and weak plant. Sap-suckers injure a plant by draining away its vital food and water-supply and they may also infect it with a disease. As evidence of the large quantity of sap removed one may find the soil beneath an attacked tree soaked with moisture and sticky with excreted sugar; black moulds grow on foliage contaminated with excreta and prevent it from function-

ing; the twigs and leaves occupied by some species are covered thickly with wax or resin. Under those disabilities the plant withers and starves. Diseases are produced in trees through the agency of sap-suckers (Aphidae, Jassidae) which act as vectors of the virus or fungus and inject it into the plant-tissues.

Predators: The predaceous bugs are effective enemies of some caterpillar pests of trees and a few have been utilised in biological control. Several species of aquatic bugs in the families Belastomidae, Corixidae, Nepidae, etc. are enemies of the larvae of mosquitoes.

In the whole world about 55,000 species of Rhynchota are named; of these about 4,500 occur in the Indian region. The whole order has been monographed in 7 volumes of the *Fauna of British India* by Distant.

Synopsis of the families of the Order RHYNCHOTA

Suborder **HEMIPTERA**

GYMNOCERATA	**Pentatomidae**
	Coreidae
	Pyrrhocoridae
	Tingitidae
	Reduviidae
	Cimicidae
	Capsidae

Suborder **HOMOPTERA**

AUCHENORRHYNCHA	**Cicadidae**
	Membracidae
	Cercopidae
	Jassidae
	Fulgoridae
STERNORRHYNCHA	**Psyllidae**
	Aleyrodidae
	Aphidae
	Coccidae

LITERATURE ON RHYNCHOTA:

Atkinson E. T., 1884-1886, *Homoptera Indica* (reprinted ex *Journ. As. Soc. Bengal*).

Distant W. L., 1902-1918, *Fauna Brit. Ind.*, Rhynchota, I, Heteroptera, pp. 438, figs. 249 — II, Heteroptera, pp. 503, figs. 319 — III, Heteroptera, Homoptera, pp. 503, figs. 266 — IV, Homoptera and Appendix, pp. 501, figs 282 — V, Heteroptera, Appendix, pp. 362, figs. 214 — VI, Homoptera, Appendix, Heteroptera, Addenda, pp. 210, figs. 89.

Fletcher T. B., 1925, *Agr. Res. Inst., Bull.* No. 162, pp. 32-41, Tentative keys to the orders and families of Indian insects.

ALEYRODIDAE

WHITEFLIES are moth-like but minute in the adult stage and scale-like in the larval stage, which can be confused with Coccidae. The name originates from those species that have the wings dusted with a white floury wax; others have black or cloudy spots and bands. Eggs are attached upright by stalks to the surface of leaves and are laid in a circular or spiral row as the ovipositing female remains in one spot and revolves. The 1st stage larva is convex or flattened-oval with functional legs. After fixing itself to the surface of a leaf and sucking the sap it moults and becomes a legless true scale with degenerate antennae. The body is usually covered with a waxy secretion which may be very profuse and at the margins take the form of filamentous or spiny processes. There are 4 larval instars, the last feeds normally, but later becomes inactive and gradually changes in shape forming a definite pupa with imaginal appendages enclosed in their sheaths. Honeydew is excreted in large quantities by all stages and this, falling on the foliage of infested plants, permits the growth of a black mould, *Capnodium* sp. The result of feeding by numerous whiteflies is discolouration and finally withering or shedding of the foliage. The length of the life-cycle in most species is 15 to 25 days and generations succeed one another throughout the year. In the winter development is slowed down and in dry hot weather the mortality is high. At least 2 species are vectors of virus diseases.

LITERATURE ON ALEYRODIDAE:

Misra C. S., 1921, *Agr. Res. Inst., Bull.* No. 103, Some Indian economic Aleyrodidae.

Rakshpal R., 1940, *Ind. Journ. Ent.*, II, i, pp. 27-43, The morphology of the genitalia in the Aleurodidae (Homoptera) and their mode of working.

Singh K., 1931, *Mem. Dept. Agr., Ind.*, XII, pp. 1-98, A contribution towards our knowledge of the Aleyrodidae of India.

— 1932-1940, *Rec. Ind Mus.*, XXXIV, pp. 81-88, On some new Aleyrodidae from Burma—*tit. cit.*, XXXV, pp. 343-346—XL, pp. 189-192—XLII, pp. 453-456 (notes on Aleyrodidae).

Aleurocanthus bambusae, A. longispinus, A. niger, A. nigricans, A. obovalis occur on the leaves of bamboos including *Dendrocalamus giganteus* and *Bambusa nana*. **A. mangiferae** on *Mangifera indica*. **A. woglumi**, a widely distributed species, on *Capparis pedunculosus*, *C roxburghi*, *Citrus* spp., *Cocos nucifera*, *Kurrimia zeylanica* and *Salacia reticulata*.

Aleurolobus marlatti on *Citrus*, *Ficus* and *Morus* spp. **A. simulus** feeds on the leaves of *Bombax malabaricum* which become yellow and spotted where an insect is attached and eventually are killed.

Aleuroplatus alcocki occurs on the leaves of seedlings of *Ficus indica* and *F. religiosa* at the end of the rainy season.

A. ficus-gibbosae on *Ficus gibbosa.* **A. ficus-rugosae** on *Ficus rugosa.* **A. pectiniferus** on *Morus* spp. and Euphorbiaceae. **A. premnae** on *Premna cordifolia.*

Aleurotrachelus multipapillus occurs on *Bambusa nana.*

Bemisia gossypiperda, the Whitefly of Cotton, is a pest of various other agricultural crops and is a fairly general feeder on shrubby growth including *Clerodendron infortunatum* and *Nyctanthes arbortristis*; 44 species of food plants are known. It has been incriminated as the vector of tobacco leaf-curl, a virus disease.

The fly, about 1 mm. long, has narrow white mealy wings and a pale yellow body. The yellow eggs are laid on the lower surface of a leaf, inserted in the tissue by short stalks, about 30 to 200 by each female, and hatch in about 3 days in the hot season but the egg-period is prolonged to over a month in the coldest season. The flattened, oval, greenish-white larva settles on the lower surface of the leaf, sucks the sap and secretes a waxy marginal fringe. There are 4 instars, the 4th passing directly into a pupal stage without a moult. In a heavy infestation as many as 500 larvae may be crowded into a square inch of leaf-surface; the leaves are drained of sap and fall prematurely. The total life-cycle is 12 to 100 days; short cycles occur in the hot period, April–September; in October–November the cycle is 30-40 days; in the cold weather 90-100 days; in March 30 days. There are possibly 12 generations per annum. Hibernation occurs in the pupal stage. Cotton plants which receive the largest number of irrigations and consequently the maximum amount of water have on an average the lowest whitefly attack; the types which receive restricted irrigations with a corresponding minimum supply of water are comparatively severely infested.

LITERATURE:

Hussain M. A and Trehan K. N., 1933, *Ind. Journ. Agr. Sci.*, III, V, pp. 701-753, pl. lv-lx, 5 figs. Life history bionomics and control of the white fly of cotton — 1940, *tit. cit.*, x, pp. 101-109, Final report on the scheme of investigation on the white-fly of cotton in the Punjab. (references to literature).

Pruthi H. S. and Samuel C. K., 1940, *Proc. Ind. Sci. Congress*, III, p 180, Biology and fluctuations in the population of *Bemisia gossypiperda* vector of tobacco leaf curl.

Dialeurodes citri, The Citrus Whitefly, a pest of *Citrus* spp., is widely distributed in India and also occurs on *Jasminum arborescens* and *J. sambac*, *Melia azedarach*, *Ricinus communis*. **D. eugeniae** on *Eugenia jambolana.* **D. decempuncta** on cinnamon and *Morus* sp.

Laingiella bambusae occurs on bamboo.

APHIDAE

PLANT Lice (or Greenfly) are rarely more than 2 mm. long, of soft delicate structure and varying in colour from yellow to

black. On the dorsal surface of the 5th abdominal segment is a pair of tube-like processes—the so called honey-tubes or cornicles—which secrete a waxy fluid that acts as a protection against predators. A sweet fluid (honeydew) is emitted from the anus and is highly attractive to ants (Formicidae) which feed upon it.

Ecology: Aphidae are remarkable for their very high fecundity and diverse methods of reproduction, their complicated life-histories and the polymorphism occurring in the different generations of the same species. The chief types are i, wingless females hatching from over-wintered eggs and producing living young parthenogenetically; these females are usually the stem-mothers or founders of the first brood of the year; ii, wingless parthenogenetic viviparous females of a slightly different type which are the progeny of type (i), iii, winged parthenogenetic viviparous females occuring in later broods and capable of migration; iv, winged males and winged females which are produced on one occasion only and late in the seasonal cycle; these pair and reproduce by laying eggs. The life-cycle of a single generation is 2 or 3 weeks. The seasonal history is further complicated by the fact that the winged forms of one generation may migrate from the original food-plant to a new host of another species of plant; or the generations may alternate between an environment in the soil at the roots or in the air on the leaves.

The attack of Aphidae contorts or crumples parts of the plant, or arrests its growth, or forms galls of great variety in shape. The ejection of honey-dew by species that feed openly may cover the surrounding foliage with sticky glaze, on which a black sooty fungus develops.

LITERATURE ON APHIDAE:

Das B., 1918, *Mem. Ind. Mus.*, VI, pp. 135-274, pls. xiii-xxx, The Aphididae of Lahore.

George C. J., 1927, *Journ. As. Soc. Beng.*, n. s., XXIII, pp. 1-12, South Indian Aphididae.

Krishnamurti B., 1930, *Journ. Bomb. Nat. Hist. Soc.*, XXXIV, pp. 411-419, Aphididae of Mysore.

Aphis odinae attacks *Bischofia javanica*, *Hamelia patens*, *Lannea grandis*, *Mangifera indica* and *Sapium sebiferum*.

Cerataphis lantaniae occurs on *Areca catechu*, *Elaeis guineensis* and *Lantana aculeata*.

Chermes abietis-piceae exhibits an alternation of generations on *Picea morinda* and *Abies pindrow* in the Himalayas.

Life-history on Picea morinda: In early spring the eggs of the 1st generation are laid by the stem-mother at the bases of unopened buds at the tips of the growing shoots of spruce. The young nymphs emerging in May feed at the roots of the undeveloped needles and the adjoining stem. The growing bud instead of developing into a cluster of needles is malformed into a green conical gall resembling a small spruce cone Cells develop in the gall or pseudocone and enclose the young aphids in colonies of 6

or 8. The galls increase to about $1\frac{1}{4}$ inches from May to July and become deep purple with the points of the arrested needles green The scales contract and narrow slits are formed through which the *Chermes* in the cells emerge and moult for the last time. The new generation consists of winged females some of which remain on the spruce and lay eggs there and the others migrate to the silver fir, *Abies pindrow*, and oviposit on the needles. Winged individuals from the early broods on silver fir also return to the spruce. The rains and autumn generation gives rise to the wingless stem-mother which hibernates and lays the eggs that reproduce the gall-formers.

Life-history on Abies pindrow: In early spring egg-masses covered with a wax-wool are laid by the stem-mothers on the bark of the branches of silver fir. The nymphs hatch and feed on the young unfolding needles; some of the nymphs mature into apterous parthenogenetic oviparous females and a smaller proportion develop into a winged form. These also lay eggs on the silver fir needles but some may migrate back to the spruce. Several generations of apterous parthenogenetic females may develop on the fir. The nymphs live on the needles at first but subsequently move down to the bases and on to the shoot. No gall is formed but the needles become contorted and are bound together in a large twisted bud by means of an exudation of resin. In July winged forms migrate from the spruce and give rise to broods on the silver fir. The generations continuing through the rains and autumn eventually produce the eggs of the spring generation.

In cases of heavy attack $\frac{3}{4}$rs of the branches of *Picea morinda* may be galled and with the continuous destruction of buds growth stops almost entirely. The contortion and dwarfing of the young shoots of *Abies pindrow* and the withering of the older needles also considerably reduces the growth.

Dasia aedificator converts the leaflets of *Pistacia integerrima* into long pod-like or horn-like galls. When the foliage buds of *Pistacia* open in spring the developing galls are visible as small protuberances at the bases of the leaflets. Each gall encloses one aphid hatched from an egg laid previously on the bud. As the foliage matures the galls grow and the mother aphids within multiply, eventually producing yellow wingless females that reproduce parthenogenetically. In the autumn when the galls are fully formed they are straight or curved green or pink pod-like structures, 5-10 inches long and 1/3 inch wide, and may contain thousands of aphids covered by a white flocculence. The winged females emerge from a crack in the side and migrate to another plant (Das). The dry galls have a medicinal value.

Eriosma lanigerum, The Woolly Aphis, or The American Blight, is a serious pest of apple trees, in practically all the apple-growing districts of India, viz.: Kashmir, Kulu, Simla,

Kumaon, Sikkim, Shillong, Coonoor, Ootacamund and the Southern Shan States. Originally a native of North America it has been distributed all over the world as a pest of apple and pear. Attacked trees produce scanty crops of apples as a result of the stunted and cankerous growth of the branches and roots and may eventually die. Thousands of trees have been destroyed by this pest in the fruit orchards in the Himalayas

Life-history: The attack of the Woolly Aphis is recognisable (a) on the stem and branches and epicormic shoots by the presence of white cottony or woolly masses of waxy filaments that are secreted by purplish aphids clustered in cracks and cankers in the bark; and (b) on the roots below ground by the formation of nodular swellings or galls, and by the decay and death of the rootlets—these swellings do not split like the cankers on the shoot. The aphids on the roots produce woolly filaments but less abundantly. The wax is secreted from glands on the head (10) thorax (12) and abdomen (30). A series of generations occurs during the warmer part of the year and gives rise to winged and wingless females. The winter is passed in the egg and young nymphal stages. The eggs are deposited, one by each female, in crevices in the bark of the stem and branches while the hibernating nymphs occur among the roots. As far as is known the whole seasonal history in India is passed on the apple tree and is spread from tree to tree by the winged and wingless forms. In its original habitat the cycle is more complex owing to the alternation of generations on elm and other host-trees from which the reinfestation of apple is caused by migrating winged adults. The Himalayan elms are not attacked. Frequent attempts have been made to introduce the parasite, *Aphelinus mali*, to Kumaon since 1927. For control measures see Part Two.

Greenidea artocarpi occurs on *Artocarpus integrifolia.*

Hyalopterus atriplicis, a cosmopolitan species, occurs on *Chenopodium album* contorting the leaves into boat-shaped pseudo-galls in which large colonies of apterous oviparous females thrive.

Myzus persicae. The Green Peach Aphis, is a severe pest of peach trees in many countries. In India it attacks garden and field crops and some trees including *Dalbergia sissoo.* It is an important agent in disease-transmission being a vector of 21 kinds of virus especially causing diseases of Solanaceae and Cruciferae.

Misra C. S., 1932, *Ind. Journ Agr. Sci.*, II, pp. 536-539, pl lvii.

Oregma bambusae occurs in close colonies on the culms and under the culm-sheaths of bamboos, *Bambusa arundinacea, B. oliveriana, Dendrocalamus giganteus* and *Thyrsostachys oliveri.*

The genus **Pemphigus** contains a large number of species making galls on the leaves or shoots of forest trees. The galls begin to develop in the spring and the number of aphids inside

a gall increases until the autumn when winged migrating forms are produced and escape. These fly to cruciferous plants where viviparous females are produced which give rise to colonies living in the soil and feeding at the roots of crucifers.

Pemphigus imaicus makes an elongate gall extending along the upper surface of the midrib of the leaf of *Populus ciliata*. **P. mordwilkoi** and **P. nainitalensis** make spherical woody galls attached to the side of a twig of *Populus ciliata*. Galls on *Populus euphratica* and *P. tremula* are formed by still other species of *Pemphigus*.

Periphyllus aesculi occurs on *Aesculus indicus*.

Prociphilus micheliae causes curling of the leaves of *Michelia champaca*.

Toxoptera aurantii, a cosmopolitan species, has a wide range of food-plants including *Citrus* species, *Celtis cinnamomea* (flowers), *Dalbergia sissoo*, *Eugenia mooniana* (twigs), *Flacourtia ramontchi* (young shoots), *Mesua ferrea* (young shoots), and tea bushes (young flush).

Tuberolachnus viminalis, a large greyish-brown aphis, occurs in north India on *Salix aegyptica*, *S. babylonica* and *S. tetrasperma* and is found also in America and Europe. Honeydew is discharged copiously and congeals into a non-crystalline sugary deposit.

CAPSIDAE

SOME of the large family of CAPSIDAE are predaceous bugs and the majority are terrestrial plant-suckers.

Ballard E., 1927, *Mem. Dept. Agr., Ind*, x, No. 4, pp. 61-68, Some new Indian Miridae.

Chatterjee N. C, 1938, *Ind. For. Rec.*, Ent., III, No. 11, pp. 220-223, Capsidae of sandal (33).

Distant W. L., 1904, *Fauna Brit. Ind.*, Rhynchota II, pp. 412-488, figs. 263-319, Capsidae.

Adelphocoris relatum and **Eurystylus burmanicus** feed on *Santalum album* and *Dodonaea viscosa*.

Helopeltis antonii is a slender bug, 6–8 mm. long, with a wide black head, red thorax, black and white abdomen and greenish-brown wings; on the scutellum is a long straight knobbed erect process. The egg is provided with 2 threads strongly curved which remain exposed. Two or 3 eggs are deposited together in a hole in soft shoots, leafstalks or midribs and sometimes in fruits. More than 200 eggs may be laid by one female who lives for several weeks. The orange coloured nymphs appear in a few days (7–10); the long legs and body form produce some resemblance to an ant. They feed at night by puncturing the soft plant-tissue, which blackens and dries. These wounds cause deformation of the leaf and shoot, or the whole shoot may dry up and die back. The total life-cycle is about 3 weeks and breeding is continuous in warm, moist weather. In Ceylon the

season most favourable to the development of *H. antonii* is the dry windy weather between the S. W. and N. E. monsoon, July to September. Among the food-plants are *Anacardium occidentale*, *Bixa orellana*, *Cacao*, *Cinchona*, *Cinnamomum camphora*, *Erythrina*, *Melia azadirachta*, *Swietenia*, tea, *Tephrosia*.

The allied **Helopeltis theivora** is the Tea Mosquito or Tea Helopeltis Bug, 6–8 mm., occurring in the Assam and Bengal tea districts. At the slowest rate of development 4 generations are completed in a year but under ultra-favourable conditions a series of 14 life cycles is possible.

Andrews E. A., *Factors affecting the control of the tea mosquito bug*. (Indian Tea Association.)

Carpenter P H. and Andrews E. A., 1922, *Ind. Tea Ass. Quart. Journ.*, On the value of different insect control methods in tea and against mosquito blight in particular.

Lucitanus punctatus and **Poecilocytus aureus** feed on *Santalum album*.

CERCOPIDAE

FROGHOPPERS or Cuckoo-spit insects constitute this family which is closely allied to the Jassidae. The nymphs, which live on plants sucking the sap, in some genera eject a frothy fluid from the anus; this froth does not readily evaporate and is produced in sufficient quantity to cover the insect completely while feeding and protect it from desiccation. In other genera the liquid excretion hardens on exposure to air. Species of *Machaerota* make cylindrical tubes to live in on *Agele marmelos*, *Phyllanthus emblica*, *Zizyphus jujuba*, etc.

LITERATURE ON CERCOPIDAE:

Chatterjee N. C. and Bose M, 1933, *Ind. For. Rec.*, XIX, ii, pp. 8-10, figs. 3, 4, Cercopidae of sandal (13).

Distant W L., 1907, *Fauna Brit. Ind.*, Rhynchota, IV, pp. 79-156, figs. 65-105.

— 1916, *tit. cit.*, VI, pp. 183-217, figs. 140-159, Cercopidae.

Lallemand V., 1933, *Ind. For. Rec.*, XVIII, I, pp. 1-14, Cercopidae of sandal (4).

Beesoniella sylvestris, 6 mm., [fig. 189] is one of the cercopids frequenting *Santalum album* in Coorg.

Clovia lineaticollis feeds on young shoots and leaves of *Artocarpus integrifolia* in south India, the nymphs in a mass of froth. The adult, 9 mm., is chestnut-brown with yellowish stripes.

Cosmocarta relata is a serious pest of *Artocarpus integrifolia* in south India sucking the young shoots. The nymphs live in small colonies inside a common mass of froth generally on the stalks of young shoots and ripening fruits. A clear liquid may be produced in sufficient quantity to wet the ground beneath the tree. The adult, 15 mm., has a reddish-yellow head and pronotum, and bluish-black forewings with reddish markings. The nymph is dark purple with a yellowish head and pronotum and legs.

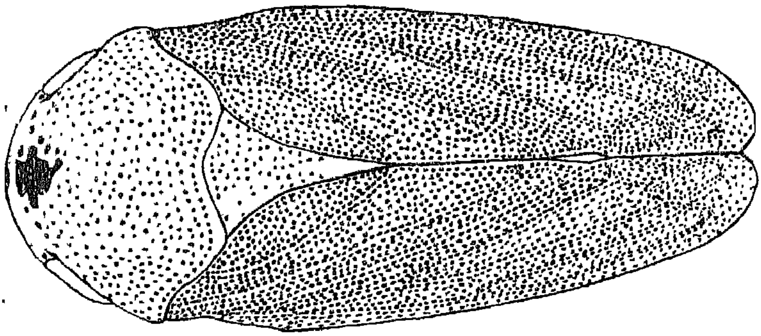

Fig. 189. Beesoniella sylvestris, dorsal view of adult, natural size 6 mm.

Machaerota planitiae, 12 mm., has the scutellum produced over the abdomen into a large curved spine (resembling those of Membracidae). It is a pest of ber and ghont trees 2 or 3 years old, particularly *if unhealthy, causing the dying back of terminal* shoots. Eggs are laid on *Zizyphus jujuba* and to a less extent on *Z. xylopyra* on the shoots, buds or leaves and in flowers, slightly inserted in the tissues. The nymph on hatching settles on the young shoot or leaf-petiole and sucks the sap. A clear frothy liquid is exuded from the anus which evaporates to a plastic material that is worked up by the nymph into a tubular covering for its body. The white shell-like tube adheres the shoot of the plant permanently and may be half an inch long. When full-grown the nymph comes outside the tube; just before moulting a clear liquid is exuded which settles round the middle and hind legs and on hardening glues the nymph to the tube. In this position the imago emerges from the nymphal skin. The life-cycle lasts about 6 weeks in the hot weather (egg 7 days, larva and pupa 35 days).

Peuceptyelus sigillifer is one of the species frequenting *Santalum album* in South India. Adults are most abundant in July-January (maximum November, minimum May), there are at least 2 generations a year.

Chatterjee N. C. and Bose M., 1933, *tit. cit.*, pp. 9, 10, figs. 3, 4.

Phymatostetha deschampsi, 10 mm., sometimes occurs in great abundance on teak foliage during the rains sucking the leaf-sap. It is preyed upon by the spiders *Sandalodes semicupreus* Sm. (Attidae) and *Oxyopes* sp. (Oxyopidae).

Ptyelus nebulosus and **P. praefractus**, 9–11 mm., suck the sap from the foliage of various trees and occasionally resort to *Santalum album* and *Tectona grandis*; the nymphs discharge large quantities of water in a fine mist.

CICADIDAE

CICADIDAE which are amongst the largest of the Homoptera have squat broad bodies and long membranous wings, frequently brilliantly coloured and patterned, and reaching an expanse of 3 inches. They are essentially forest insects, living in plant associations rather than on single plant-species and are general feeders on the more succulent parts of the trees. Although rarely seen they strike very forcibly on the ear with the great volume of sound produced by the males—a noise that may be compared to that of a high-speed circular saw or of a steam whistle and is certainly equalled by no other insect. The "shrill vibrating note resounds through the moist woods. At times all is silent; then a single sound rings out from a point high up upon a tree; a second soon adds to the music; a host of others then join the chorus, until the whole forest trembles with the noise" (Hingston). In the dry sandal forests of south India cicadas spend the nights in the crowns of tall trees. The males sing from some hours after sunrise till the middle of the morning, becoming sluggish with the increasing heat and resting in deep shade until evening when there is a final burst of song.

Sound-organs: The sound-producing apparatus of the cicada occurs on each side of the lower surface of the 1st abdominal segment. In some species the true sound-organs are exposed to view, in others they are concealed by broad plate-like extensions of the metasternum. The principal part of the sound-apparatus is a cavity closed by a taut membrane which is rapidly vibrated by the shuddering of powerful muscles attached to its inner face and to the 1st abdominal sternite. In some species the drum-membrane has transverse chitinous ridges and a narrow chitinous plate with a median tooth. In the one case the production of sound is comparable to the pushing in and out of the bottom of a tin vessel; in the other it is a click made by the chitinous tooth striking against the corresponding ridge. Other structures may be present which act as sounding-boards and intensify the vibrations of the drum. Inside the abdomen is a large air-sac; when this is partly inflated the note produced is low, when it is distended the note rises in pitch. The large plate-like flaps from the metathorax probably affect the intensity of the note and direct the sound by variation in the size of the orifice of escape, but are mainly protective. The object of the "singing" of male cicadas is unknown.

The adults suck sap from slender shoots and twigs and longer soft-barked stems and branches up to about 8 inches in girth. When feeding the beak is held at right angles to the head, the thorax is raised and the abdomen is pressed close against the stem; the stylets penetrate about 1/3rd of their length through a minute puncture. In this position the cicada feeds for hours, ejecting the fluid excreta in a jet that bursts into fine spray. Eggs are laid in contiguous oblique rows of 10–20 in slits 1½ to 2 inches long in the bark. The nymphs on hatching drop to the ground and spend their lives in the soil where they feed by sucking the sap from the smaller roots of trees. The life of the nymph is unusually long; nothing is known of the length of the life-cycle of Indian cicadas but an American species has a cycle of 13 to 17

years When mature they emerge from the soil, leaving a circular hole and climb up the stem of a tree or other elevated surface and transform. The nymphal skin is very thickly chitinised and remains without much shrinking or distortion attached to the bark after the insect has emerged. The femora and tibiae of the fore-legs are modified into flattened and toothed organs used for digging and scraping in the soil.

LITERATURE ON CICADIDAE:

Chatterjee N. C., 1936, *Ind. For. Rec.*, Ent., II, No. 3, pp. 115-124, Cicadidae of sandal (28).

Distant W. L., 1906, *Fauna Brit. Ind.*, Rhynchota, III, pp. 55-174, figs. 31-80 — 1916, *tit. cit*, VI, pp. 1-16, figs. 1-7, Cicadidae.

Ollenbach O. C., 1928, *Ind. For. Rec.*, XIII, VI, pp. 271-281, pl., New species of Cicadidae and Fulgoridae from India and Burma.

Aola scitula, Cryptotympana intermedia, Limuriana apicalis, Platypleura capitata, P. hampsoni, and **P. octoguttata** feed on *Santalum album* in south India. It has been proved experimentally that these species do not transmit the virus of spike disease.

Paharia casyapae occurs in coniferous forests in Kashmir; it oviposits in the branchlets and stems of *Cedrus deodara* and *Pinus excelsa* so profusely that small trees are killed.

CIMICIDAE

Cimex rotundatus. The Bed Bug lays eggs, which are oblong sculptured and white, in cracks in furniture, wooden beds, mats, flooring and walls. The nymph emerges by the removal of a small lid at one end of the egg after 5-10 days; they are similar in form to the adult but more transparent and lighter in colour. After 5 moults they mature and the life-cycle varies from 2 to 6 months. A meal of blood appears necessary to ensure each moult When sucking blood the bug injects saliva causing a flow of blood to the wound. Bed bugs are nocturnal hiding by day in cracks and shelters and are particularly prevalent in dirty houses.

COCCIDAE

SCALE Insects and Mealy Bugs feed on the sap of flowers, stems, bark and roots of living plants; they cannot survive on the wilted or dead plant. The scale insects, which make up the majority of the family, consist of species that are immobile, fixed to the plant by their mouth-parts or by their excretions and moulted skins; the mealy bugs are active for most of or an essential part of their lives. In all groups the 1st nymphal period is the time of active dispersal of the species. Quiescence or fixation is continuous and complete in the female sex and is associated with the production of eggs or young. Adult males of many species have wings and fly. Most species of coccids are individually minute and inconspicuous but are easily discovered when congregated in

masses or when covered with the waxy or resinous matter excreted from their bodies; this excretion varies on each female from only a minute disc or scale of wax to a waxy ribbon 5 or 6 inches long, or to a hard encrustation an inch thick as over a colony of lac insects. Nymphs of male coccids moult 4 times and those of females 2, 3 or 4 times. The life-cycle of leaf-feeding species is often very short, 5 or 6 weeks; lac insects have 2 or 3 generations a year; large mealy bugs have an annual cycle.

The family Coccidae is of great economic importance because (a) many species are serious and fatal pests of cultivated plants, several polyphagous forms having been spread by commerce all over the world, (b) a few species like the lac insect, wax insect, and cochineal insect produce substances of value to man, and (c) a few species such as prickly pear bugs can be utilised to destroy or control noxious weeds. The coccid fauna of the Indian region has been studied principally by Green and Ramakrishna Ayyar, and one species the lac insect, is unique in having a Research Institute founded solely for its study.

LITERATURE ON COCCIDAE:

Ayyar T. V. R., 1921, *Journ. Bomb. Nat. Hist. Soc.*, XXVI, pp. 621-628, Some South Indian coccids of economic importance. — 1926, *tit. cit.*, XXXI, pp. 450-457, Recent additions to the Indo-Ceylonese coccid fauna. — 1936, *tit. cit.*; XXXIX, pp. 146-148, Notes on Coccidae from South India.

— 1929, *Agr. Res. Inst.*, Bull. No. 197, A contribution to our knowledge of south Indian Coccidae (replacing Bull. 87).

Chatterjee N. C. and Ayyar T. V. R., 1936, *Ind. For. Rec.* Ent., I, No. 12, Coccidae of sandal (26).

Green E. E., 1896-1932, Coccidae of Ceylon, I-V.

— 1919, *Rec Ind. Mus.*, XVI, pp. 433-449, pls. xxvi-xxxi, Notes on Indian Coccidae of the subfamily Diaspidinae.

— 1937, *Spol. Zeyl*, XX, pp. 277-341, An annotated list of the Coccidae of Ceylon with emendations and additions to date.

Ramachandran S. and Ayyar T. V. R., 1934, *Imp. Counc. Agr. Res. Misc. Bull.* 4, Host plant index of Indo-Ceylonese Coccidae (Literature).

Anomalococcus indicus is a dome-shaped scale on *Acacia arabica* and *A. leucophloea* and is abundant on weakened trees. (Ayyar, 1929, pl. xix, coloured).

Aspidiotus camelliae occurs on *Michelia champaca* and numerous species of trees (Chatterjee and Ayyar, 1936, p. 236).

Aspidiotus destructor, The Coconut Scale, is a widely distributed pest of coconuts, other palms and various cultivated plants. Dense colonies of scale insects appear as yellow patches on the undersurface of the leaf. The sexually mature female scale produces eggs which develop inside the body and are eventually laid in a ring of about 50 round the female under the protection of a thin waxy shield. The larvae settle near the parents, or scatter or are blown by wind to the other trees. The males are winged. In a warm climate the scale breeds continuously throughout the year but development is somewhat retarded in long wet periods.

Ayyar T. V. R., 1929, *tit. cit.*, p. 21, pl. vii, fig. 1.
Hutson J. C. 1933, *Dept. Agr. Ceylon*, Leaflet. No. 78, and 1933, *Trop. Agr.*, LXXX, pp. 254-256, 1 pl.

Aspidiotus orientalis is flattish, circular to more or less oblong, 1·6 mm., and varies in colour from yellow or pale brown to dull reddish-brown. It attacks a number of trees including *Butea frondosa*, *Cassia fistula*, *Chloroxylon swietenia*, *Cocos nucifera*, *Cordia myxa*, *Dalbergia sissoo*, *Melia azadirachta*, *Santalum album*, *Schleichera trijuga*, *Swietenia mahagoni*, *Tamarindus indica*, *Zizyphus jujuba*, *Z. xylopyra* and various shrubs and garden plants.

The scale thickly covers the shoots and stems of about ½-1 inch in diameter, appearing on the new shoots and often spreading to the leaves. It also infests certain fruits such as tamarind and the winged seeds of shisham. In severe infestations the growth is retarded, leaves are shed and the stems die back; young trees may be killed. It is a pest of major importance in lac cultivation, particularly in plantations where *Zizyphus jujuba* and *Schleichera trijuga* are the lac hosts. Trees attacked by *A. orientalis* cannot be used for infection with lac. *A. orientalis* is parasitised by *Tetrastichus purpureus* (Eulophidae), which is a primary parasite of the lac insect, and hence the presence of the scale is also a source of parasitism to the lac insect. In irrigated plantations of *Dalbergia sissoo* outbreaks of the oriental scale occasionally occur and cause shedding of the foliage and drying of the branches resulting in stag-headedness or death. Its centres of propagation are the backward areas and localities unsuitable for shisham and from these it spreads to well-grown stands. Considerable overlapping of generations occurs, young and adult females, adult males and nymphs are frequently present at one and the same time. The infestation gradually increases and may work up to serious proportions at three seasons in the year.

Beeson. 1938, *Ind. For. Rec.* Ent, IV, No. 1, pp. 20-21 (control).
Chatterjee N. C. and Ayyar T. V. R., 1936. *Ind. For. Rec.*. Ent., I, No. 12, pp. 235, Sandal Coccidae, (26) (biology, food-plants).
Glover P. M. 1933, *Indian Lac. Res. Inst*, *Bull*. 16, 2 figs, 1 pl, Aspidiotus orientalis, its economic importance in lac cultivation and its control.

Aspidiotus perniciosus. The Pernicious Scale or San Jose Scale, a native of northern China is a world wide pest of fruit orchards attacking apple, apricot, loquat, peach, pear, plum, quince, currant, walnut, fig, *Salix* spp. etc. It reached India in 1911 and was notified in 1933 as a pest in Kashmir and Jammu under Plant and Crop Regulation, No. 1, of 1990 where it has threatened the existence of orchards of apple, pear and plum. It is a well established pest requiring regular spraying treatment in the Beas Valley, Kulu, the Simla Hills, Kurram valley and parts of Hazara, and was notified in 1941 under the Destructive Insects and Pests Act. In Corea it is reported as having invaded virgin forests of red pine and to be killing off overmature trees;

the coniferous forests of the Himalayas are so far not affected, but it occurs on willow in Kashmir, and has been found as low as 1,200 feet above sea-level in Peshawar. It is likely to attack *Aesculus*, *Alnus*, *Betula*, *Celtis*, *Eucalyptus*, *Fagus*, *Fraxinus*, *Morus*, *Populus*, etc.

The female scale is a round flattened disc about the size of a pin-head and occurs on the bark of stems and twigs or the rind of fruits. The bark of a tree infested with San Jose Scale has a greyish, roughened, scurfy and scabby appearance; when rubbed it produces a yellowish liquid resulting from the crushing of the soft bodies of the females below the scales. Green epidermis of young shoots shows a pink or scarlet circular spot where each scale settles.

Vernacular Leaflet *Dept. Agric., Jammu and Kashmir*, Instructions regarding control of San Jose Scale in Kashmir.

Rahman K. A., 1940, *Ind. Farm*, I, pp. 387-390, pl. 97, 98, the San Jose Scale—a warning.

Aspidoproctus cinerea occurs on *Acacia arabica*, *Anogeissus latifolia*, *Santalum album*, *Terminalia* spp.; this is one of the largest coccids known. Ayyar, 1929, pl. xxix, fig. 2, 2 (a) (Walkeriana). **A. xyliae** occurs on *Pithecolobium dulce* and *Xylia xylocarpa*. Ayyar, 1929, pl. xxx.

Beesonia dipterocarpi

The gall [fig. 190] made on green shoots of *Dipterocarpus tuberculatus* in Burma is a large irregularly foliacious mass of grouped and hypertrophied leaf-like or petal like growths resembling somewhat a chrysanthemum flower but of a woody texture; at the bases of the clusters of petals are cavities in a hard woody core. A gall may contain 10 to 20 cavities each of which contains a fully developed 3rd stage female. Each female rests with the hind end directed outwards usually in close connection with a crack or tube leading to the surface of the gall, and with the fore end attached to the lining tissue of the cavity. The exuviae of the 2nd stage female is enormously distended at the frontal end so as to enclose the whole body of the 3rd stage female (the rest of the skin of the 2nd stage female is seen in fig. 190, No. 3 as a tail or stalk). The adult female is a tumid, globular or ovate form, 6-10 mm. long, 5-7 mm. wide, the hinder extremity rigidly densely chitinous and the anterior half of the body at first colourless and membranous but later darkening and hardening. [fig. 190, No. 3]; there are no limbs or antennae and the mouth-parts are obscure; the spiracles and anal orifice and other organs of this remarkable coccid are displaced and concentrated around the small posterior prominence. The male is winged, about 2 mm. long.

Ceroplastes actiniformia is a wax-scale found on *Alstonia scholaris*, *Santalum album*, and *Sapium sebiferum*. Ayyar, 1929, pl. xii, fig. 2. **C. ceriferus** on *Boswellia serrata*, *Buchanania*

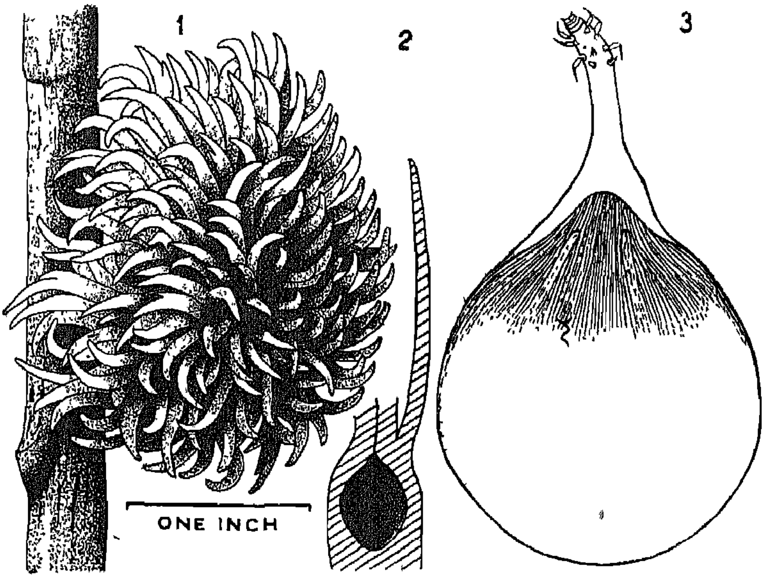

Fig. 190. Beesonia dipterocarpi.

No. 1—Gall formed on *Dipterocarpus tuberculatus.*

„ 2—Section through base of group of foliae showing chamber occupied by a 3rd stage female.

„ 3—A 3rd stage female enclosed in the distended skin of the 2nd stage (considerably magnified).

(The one inch scale applies only to No. 1)

latifolia and *Melia indica.* **C. indicus** on *Helicteres isora.* **C. pseudoceriferus** on *Diospyros montana* and *Melia indica.*

Chionaspis acuminata occurs on leaves of *Bassia latifolia, Carissa* sp., figs and tamarinds. Ayyar, 1929, pl. v, fig. I. **C. dilatata** on leaves of *Ficus, Mangifera indica, Myristica fragrans* and palms. Ayyar, 1929, pl. vi, fig. 2. **C. elongata, C. longissima** and **C. spiculata** occur on leaves of bamboos. **C. engeddensis** occurs on *Tamarix articulata* in the Punjab plantations, causing the foliage to wither and fall. The attack is accompanied by the development of a black smut which assists defoliation. **C. vitis** occurs on *Elaeagnus latifolia, Mangifera indica,* and *Vitis lanceolaria.* The infested leaves lose their colour and become yellowish-white. Ayyar, 1929, pl. vi, fig. I.

Females of the genus **Dactylopius** are covered with a profuse secretion of white cottony or mealy wax. The body contains a deep red or crimson fluid from which cochineal dye is obtained. Two species are of importance as pests of prickly pear in India and have been used successfully in the biological control of these plants. In distributing the coccid, pieces of infested prickly pear

are introduced into clumps, preferably on the shady side and in the absence of rain and wind, so that the young larvae may swarm and spread on to the healthy prickly pear. The small red larvae settle and begin to cover themselves with a white cottony secretion in a week or ten days. Gradually the surface of the pear becomes covered with close masses of white cottony material and eventually small tubular cases are formed from which the winged males emerge and after mating die. The life-cycle of the female lasts about 45 to 50 days. Continuous rains, severe cold and great heat afford conditions unfavourable to the development of the coccids. In the course of a few months a colony multiplies and spreads over adjacent clumps.

Further details are given in 'Prickly pear and cochineal insects' by J. C. Hutson, *Trop. Agr.*, 1926, pp. 229-237; 'The Coccidae of the prickly pear in south India and their economic importance' by T. V. Ramakrishna Ayyar, *Agric. Livestock Ind.*, I, pp 229-237, pl. xiii-xv, (1931); 'Present position in regard to the control of prickly pear (Opuntia dillenii, Haw.) in Ceylon by the introduced cochineal insect, Dactylopius tomentosus Lamk', by F P. Jepson, *Trop. Agr*. lxxv, pp. 63-72 (1930); 'Prickly pear and cochineal insects' by Beeson, *Ind For.*, 1934, pp. 203-205; and in 'Eradication of prickly pear by cochineal insects in the Bombay Presidency', *Agric. Livestock Ind.*, 1935, v, pp. 36, 42.

Dactylopius cacti, the True Cochineal Insect. The female is larger than those of *indicus* and *tomentosus* with a less abundant mealy covering; the dermal pores are thick-rimmed and in large clusters; the truncate spines are inconspicuous and slender and often tapering. It is known under the commercial name of Grana fina. This species is a native of Mexico whence it has been introduced into various countries for the production of cochineal dye. It does not appear to have been permanently established in India. It feeds on *Opuntia coccinellifera* but will not survive on the other species of prickly pear wild in India.

Dactylopius ceylonicus = *D. indicus.*

Dactylopius indicus. The Wild Cochineal Insect. The female of *D. indicus* after removal of the white cottony covering is brownish-red, 2-4 mm. in diameter, and is somewhat larger than *D. tomentosus* from which it differs in that the dermal pores are relatively small and in groups of 3 or 4 (in *tomentosus* large and in clusters of 2 to 16); the truncate spines are very broad at the base (in *tomentosus* longer than the basal breadth). It breeds only on *Opuntia monacantha* (= *vulgaris*), the prickly pear with single straight spines dark at the apex.

Economic importance: This species, in spite of its name, is not indigenous to India. It was the first cochineal insect to be introduced to India about 1795 or earlier, and apparently in mistake for the true cochineal insect *D. cacti.* Propagation was started in the Calcutta Botanical Gardens on *Opuntia monacantha* and also in Madras. As a commercial proposition the venture was not a success for *D. indicus* is much

inferior to *D. cacti* in the production of cochineal dye. The industry gradually lost importance and the work was soon stopped, but the coccid ran wild from the centres of propagation and spread rapidly on the wild prickly pear in different parts of India. By the middle of the 19th century much of the prickly pear (*Opuntia monacantha*) in northern and central India was infested and destroyed by this insect. About this period it was introduced into Ceylon from Madras and established on *O. monocantha* which it soon brought under control. *D. indicus* has followed *O. monocantha* into the sub-Himalayan tract of the Punjab where it periodically destroys the cactus. Attempts were made in the latter half of the 19th century, by distributing *D. indicus*, to exterminate prickly pear which had become a widespread pest in South India. But the commonest species of prickly pear in the south were *Opuntia dillenii* and *O. elatior* (=*nigricans*) on which *D. indicus* does not feed, and consequently these attempts were foredoomed to failure; yet it was not until 1911 that this fundamental error was discovered by Burkill. By 1914 the formerly widespread *O. monacantha* had become relatively uncommon in northern India and practically extinct in the south, a result caused entirely by *D. indicus* which is itself now comparatively rare. In 1913 *D. indicus* was introduced from Ceylon into Queensland where it has practically exterminated *O. monacantha*.

Dactylopius opuntiae = *D. tomentosus*.

Dactylopius tomentosus. The female of *D. tomentosus* is smaller than that of *indicus*; the 7th antennal segment is slightly longer than broad; the dermal pores occur in large clusters of 2 to 16; the trucate spines are comparatively longer than the basal breadth. This species breeds chiefly on *Opuntia dillenii* in India, the prickly pear with straw-coloured curved spines in clusters of 2 to 5; it thrives very well on *Opuntia elatior* (= *nigricans*) but does not survive on *O. monocantha* or *O. ficus-indica* (= *decumana*).

Economic importance: In 1924 the Government of Ceylon received a consignment of this American insect from the Australian Commonwealth Prickly Pear Commission which had imported it from North America. It was distributed in the large tract of country in the north of the Island which was overrun by *O. dillenii*; and in the course of 4 or 5 years completely destroyed the prickly pear in many centres. From Ceylon it was introduced into south India and Mysore, in 1926, since when it has spread rapidly in adjacent districts and has been distributed in many localities in the Peninsula (in Madras and Central India.) By 1930 it was established over an area of about 40,000 square miles. By 1933 it had reached Delhi. Between 1931 and 1934 it was propagated over large areas in Bombay Presidency on *Opuntia elatior* (= *nigricans*).

adjoining larvae eventually meet and coalesce in a continuous encrustation.

A part of the population is male; the males mature quickly and leave their cells, the lac forming which is small and of no commercial value (**emergence of males**). There are two kinds of adult males, winged and wingless; both kinds are sexually potent and fertilise the females within the cells through the anal tubercular openings (**fertilisation**). In the absence of a male it is possible for a female to reproduce asexually and to yield abundant progeny and good lac (**parthenogenesis**). The pregnant female continues to grow and secrete lac until the period of oviposition at the end of her life (**crop maturity**).

In the wall of the cell of a single female there are 3 openings, the respiratory or **brachial pores** and the anal **tubercular pore**, through which white filaments of wax protrude; the function of the filaments is to keep the pore open while the lac is being added and their presence indicates the lac insect is alive and healthy but if they are broken off it does not mean that the insect is unhealthy. Through the tubercular pore honeydew is ejected and is the attraction for ants.

The **life-cycle** recurs twice a year on the same host-tree in central India, and 3 times a year (13 months) in Mysore, and twice a year in Ceylon but without seasonal swarming-periods. The periods of each generation vary with the species of tree on which the lac insect is growing; in central India it is possible for 4 lac **crops** to be taken in one year with *Schleichera trijuga* as one host; these 4 crops are named after the Hindi months in which they are cut. Lac grown on or from brood-lac of *S. trijuga* is termed **kusmi** lac and that on other host-trees is **rangeen** lac.

The following synopsis gives the principal events in the 4 lac crops :—

Infection	Emergence of males	Crop reaped	Females mature
	RANGEEN CROPS		
Katki—June-July	Aug.-Sept.	Oct.-Nov.	Oct.-Nov.
Baisakhi—Oct.-Nov.	Feb.-March	Apr.-May	June-July
	KUSMI CROPS		
Aghani—June-July	Sept.	Dec.-Jan.	Jan.-Feb.
Jethwi—Jan.-Feb.	Mar.-Apr.	June-July	June-July

Lac cultivation

Shellac (the manufactured product after washing and melting

stick lac) possesses a peculiar combination of properties which have not yet been duplicated by synthetic resins although synthetic substitutes have replaced it for some uses. To meet this competition and to extend its consumption shellac prices must remain relatively low and at such a level its production from special lac plantations cannot be an economic proposition although the principles of scientific cultivation are now well defined. There is, however, a wide gradation between the methods of an ideal plantation and those of raiyat cultivators. Systematic lac-culture on jungle land, methodical rotation, pruning, infection, tending, harvesting, storing and marketing are fully justifiable and can be made profitable. Full data on the subject are available in Glover, 1937; a simple guide is by Sen Gupta, 1937; for Ceylon see Pinto, 1940; for Burma see Withers and Simmons, 1925; for Indo-China see Mehdihassan's translation of Hautefeuille, 1925; for Malaya see Miller, 1933-37. For biological control see Part Two.

Economic importance

The production of lac is virtually a monopoly of India where about 85 percent of the world's total output is grown. The main zone of cultivation is Chota Nagpur (60 percent of India's total), the Feudatory States of Orissa, Central Provinces and some adjacent areas in Bengal and the United Provinces. To a minor extent lac grows as far afield as Travancore, Sind, Kashmir, Nepal and the Shan States. The quantity of **stick lac** (raw lac scraped from the stick) collected in India is over 50,000 tons a year (a record of 60,000 tons was reached in 1936-37). When worked up into **seed lac** (stick lac after grinding and washing) and **shellac** the exported products amount to about 32,000 tons a year. Less than 4,000 tons of stick lac (=2,300 tons shellac) are retained annually for use in India. The prices of lac and its derivatives fluctuate very widely but one may put the average annual value of the exported products at about two million pounds sterling. Statistical data are available in the *Report on the marketing of lac*, 1941. As a minor forest product lac surpasses in value all other minor products but the annual revenue obtained by forest departments in Indian states and provinces varies greatly. Lac is a very complex substance comprising lac resins and wax, albuminous matter, sugars, a water soluble dye and an alkali soluble dye. The principal uses of these substances are in gramophone records, electrical insulation, paints and varnishes, hat stiffening, sealing wax, moulding powders and cements; the dyes were formerly important but have been superseded by synthetic dyes. For further details and for information on the possibility of increasing the uses of lac and shellac in India see Sen and Ranganathan, 1939.

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Lecanium longulum is a scale occurring on *Acacia farnesiana*, *A. catechu*, *Cajanus indicus*, *Casuarina equisetifolia*, *Flemingia congesta* and *Zizyphus jujuba* and is occasionally a serious pest in the Casuarina plantations on the east coast of Orissa and Madras

Monophlebus see **Drosicha**

Naiacoccus serpentinus forms white cylindrical tubes about ½ to ⅔rs of an inch long, irregularly twisted on the branchlets of *Tamarix articulata* and *T. dioica*. It sometimes occurs on *Casuarina equisetifolia* also in the Punjab.

Orthezia insignis. The country of origin of this wide spread polyphagous scale insect is unknown, it was observed in Ceylon in 1893 and in 10 or 15 years had spread on lantana all over the island. Prior to 1915 it was introduced to the Nilgiris and later to Bangalore and in 1933 to North Salem division, Madras, where it was propagated on *Lantana aculeata* until its dangerous nature was appreciated It is, however, one of the few agents that will kill lantana, feeding by the bug causes the leaves to be shed and green shoots to die back. It thrives better under shade than in the open and can destroy dense lantana scrub into which very little light penetrates But it attacks a large number of cultivated plants and it is unlikely that it could be used successfully in the biological control of lantana except under the most strictly supervised experimental conditions.

The adult greenish female develops a long white tube at the hind end of the body and deposits in it over 100 eggs The nymph has a shorter tube or none and there are white conical tubercles

along the sides of the body and 2 white streaks on the back. A generation matures in 8–10 weeks with 3 moults. The progeny is usually entirely female.

Beeson and Chatterjee N. C., 1940, ***Ind. For. Rec.***, Ent., VI, No. 3, p. 47.
Anon. 1931, ***Dept. Agr. Mysore***, Circ. No. 46, The lantana bug, pls. i, ii.

Parlatoria blanchardi is the Date Scale, probably the most serious enemy of the date palm, *Phoenix dactylifera*, and other palms of which it infests the fruit and leaves.

Pedroniopsis beesoni, 1·5 × 1 mm., lives in cracks and pits in the bark of *Shorea robusta*, producing white cottony fillaments but otherwise exposed.

Pseudococcus deceptor and **P. tectonae** live on the foliage of *Diospyros* spp. and *Tectona grandis*. **P. virgatus** infests *Poinsettia pulcherrima*, *Trachelospermum jasminoides* and various plants including *Lantana aculeata* but does not appreciably injure the last. (Ayyar, 1929, pl. xxi, fig. 2).

Pseudopulvinaria sikkimensis occurs on *Castanea* spp. and *Quercus serrata.*

Pulvinaria azadirachtae occurs on *Holarrhena antidysenterica* and *Melia indica*. **P. cellulosa** on *Murraya koenigii.*

Pulvinaria maxima, the Nim Scale, attacks *Litsaea polyantha*, *Melia indica*, *Morus indica*, *Zizyphus jujuba* and various cultivated plants. It is a serious pest of nim in central and south India. An infested tree in an advanced stage of attack is recognised by the thick coating of white mealy patches, the egg-sacs, on the foliage, shoots and bark. The female is 8–9 mm. long and 4–5 mm. wide; the body is soft and leathery, dark brown with a white waxy bloom. An unusually large egg-mass, 15–16 mm. long, is produced containing 600–900 eggs in a white cottony mass. Hatching takes about 2 weeks. The larvae swarm over the leaves and shoots. The winged males are completely developed in about 5 weeks and soon after emergence from the puparium they pair with the wingless females. After fertilisation the females grow rapidly in size and feed voraciously with copious exudation of honeydew; the ground below heavily infested branches is often soaked with the honeydew. After about a week, during which a female may change her feeding-place more than once, egg-laying begins. A life-cycle takes 6½ to 8 weeks (egg 12–14 days, male larva 4–5 weeks, female larva 5–7 weeks). Six generations may occur in a year. For control see Part Two.

Ayyar T. V. R., 1925, ***Mem. Dept. Agr. Ind.***, Ent., VIII, No. 12, The Nim Mealy Scale.

Ripersia resinophila attacks young *Pinus excelsa* and *P. longifolia*, infesting the leading and lateral current shoots of yearlings and saplings; it is commonest on trees under 10 feet high but also occurs on the twigs of large trees. The orange or purplish adult female, 3–4 mm. in diameter, lives in a resinous cell atthe bases of the needles of the growing-shoot. Eggs are ex-

truded around the body of the female. The minute pink larvae of the first brood of the year emerge in May, June, and scatter on the needles whence they are blown by wind to other trees. At first they settle in paired rows on the needles and later move to the bark of the shoot between the bases of the needles where they feed throughout the monsoon-season. The older larvae and young females are protected by a mealy dust and cottony filaments of wax but are subsequently enclosed in cells in the resin which exudes from the attacked shoot and forms a white encrustation along its whole length. In the rain the resin softens and a mould grows on it turning black on fructifying. There may be more than one generation during the monsoon. In autumn and through winter and spring the females survive in their cells on the terminal shoots together with extruded eggs some of which hatch; the young larvae hibernate at the bases of the needles and do not swarm until early summer.

This pine coccid is a pest of young chir regeneration, particularly on exposed sites at low elevation and in areas that have been burnt in previous years. The height-growth of the shoot is stunted or ceases although the needles attain full length; a newly attacked shoot shows up as a dense brush of long bright green needles. In later stages of the infestation the branches die and turn black and finally the tree dies and patches of regeneration are wiped out. For control see Part Two.

Saissetia hemisphaerica, the Brown Bug of Coffee, is a domed scale occurring on numerous species of trees including *Santalum album*. (Ayyar 1929, fig. 5, Lecanium). **S. nigra**, the Black Bug of Coffee, likewise occurs on numerous species of trees. It can be a serious pest of sandal, *Santalum album*, covering the young plant profusely with sugary excretion and black mould so that the branches die. There are probably 3 generations a year in south India. It has been proved experimentally that these scales do not carry spike disease. (Chatterjee and Ayyar, 1936, pp. 237-239).

Tachardina lobata is a lac insect occurring on *Flacourtia ramontchi*, *Michelia champaca*, *Thespesia populnea*. **T. ternata** on *Acacia sundra*.

COREIDAE

VERY little is known of the ecology of the COREIDAE (and the allied family Lygaeidae) on forest trees; 46 species frequent *Santalum album* in south India. All are sap-suckers and many species are polyphagous.

Chatterjee N. C., 1936, *Ind. For. Rec.*, Ent., II, No. 7, Coreidae and Berytidae of sandal (29).

Distant W. L., 1902-1918, *Fauna Brit. Ind.*, Rhynchota I, pp. 331-424, figs. 202-249—IV, pp. 466-487, figs. 274-280—VII, pp. 151-173, figs. 75-79, Coreidae.

Anoplocnemis phasiana occurs throughout India as a pest of agricultural crops. It sucks and causes the wilting of young shoots

and foliage of *Acrocarpus fraxinifolius*, *Aegle marmelos*, *Cassia occidentalis*, *Erythrina indica*, *E. lithosperma*, *Lannea grandis*, *Michelia champaca*, *Santalum album*. The adult, 1 inch, is dark brown to black; the hind legs have the femora enlarged and thickened and in the male furnished with a large tooth. It can eject a spray of odorous irritating liquid from a protrusible organ at the end of the abdomen. Eggs are laid in a string of 10–20 along a stem of the plant; the egg is a cushion, U-shaped in section, 2·5 mm. long. Hatching takes 6–10 days in June–July. The newly hatched nymph is black and resembles a *Cremastogaster* or *Camponotus* ant; the brood feeds gregariously during the 1st instar which lasts 3 to 5 days. In the 2nd instar the fore tibiae are enlarged and the nymph resembles a young mantis; there are 5 nymphal stages and probably 3 or 4 generations a year. Hingston's essay on the protective adaptations of this species describes an interesting aspect: "First we have camouflage or harmonization. The eggs blend with the supporting stem. Then comes deceit or simulation. The insect lifts its abdomen to suggest a sting, and grows a pair of flattened front legs that give the impression of cutting blades. At the same time another device develops, the drapery it manufactures of blackened leaves that blend both with its colour and shape. With growth these and other ruses cease to be effective. Then the creature takes to dropping to ground Also it develops two pores on its back from which it squirts an offensive juice. But its wings grow and cover these pores. Consequently it develops another machinery, a telescope at the end of its abdomen from which issues a nauseous jet. One last touch completes the system. This is the warning flash of colour, the red signal of danger which illuminates its flight".

LITERATURE:

Fletcher T. B., 1919, *Agr. Res. Inst.*, Bull. No. 89, pp. 85, 86, fig. 49.

Hingston R. W. G., 1929, *Journ. Bomb. Nat. Hist. Soc.*, XXXIII, pp. 341-346, pl. i, ii, A study in insect protection.

Ayyar T. V., *Agr. Dept. Madras*, Bull. No. 34, p. 15, fig. 10.

Chatterjee N. C., 1936, *Ind. For. Rec.*, Ent., II, No. 7, p. 159.

FULGORIDAE

An assemblage of very diverse forms ranging from the bizarre multicoloured giant Lantern Flies, with a wing-expanse of 4 inches, to small inconspicuous Plant-hoppers. The nymphs of many species carry protective waxy exudations of fantastic design; several are strongly gregarious assembling on leaves and shoots in deceptive formations. Typically there are 3 generations a year and the adult is long-lived. Several of the 43 species which frequent *Santalum album* have been tested for their ability to transmit spike disease but none has produced suspicious symptoms.

LITERATURE ON FULGORIDAE:

Chatterjee N. C. and Bose M., 1934, *Ind. For. Rec.*, XIX, viii, pp. 14, figs. 2, Fulgoridae of sandal (18).

Distant W. L., 1906-1916, *Fauna Brit. Ind.*, Rhynchota, III, pp. 175-491, figs. 81-266—VI, pp. 17-145, figs. 8-105, Fulgoridae.

Ollenbach O. C., 1929, *Ind. For. Rec.*, XIII, vi, pp. 9-11, pl. New Cicadidae and Fulgoridae.

Eurybrachys tomentosa

Food-plants are *Albizzia lebbek*, *Argyreia cuneata*, *Cajanus indica*, *Cassia fistula*, *Calotropis gigantea*, *Cipadessa fruticosa*, *Crotalaria paniculata*, *Dichrostachys cinerea*, *Elaeodendron roxburghii*, *Erythrina lithosperma*, *Santalum album*, *Scutia indica*, *Terminalia tomentosa*, *Vitex negundo*, *Zizyphus jujuba*, *Z. oenoplia*. Peninsular India.

Life-history: Eggs are laid in oval clusters of 30 to 40 on the surface of a leaf or on bark. The egg-masses are rendered conspicuous by the deposition on them of a covering of white flocculent wax which is derived from 2 wax-secreting plates at the anal end of the abdomen of the female. One female may lay 6 egg-masses or about 200 eggs which hatch in 2–3 weeks. The newly hatched nymphs are at first more or less gregarious but scatter after a day or two and suck sap at the axils of leaves or young shoots. There are 5 nymphal instars, feeding in the first 3 stages on new leaves and tender young stems and in the 4th and last stages on shoots that are either green or partly suberised. The feeding-puncture leaves a ring-shaped mark. Both healthy and diseased shoots of *Santalum album* are attacked. Nymphs of all stages, but particularly the 5th, are restless when disturbed, walking quickly to the opposite side of the leaf or twig, or else jumping away. Just before jumping the leaf-hopper usually raises the end of the abdomen and the brushes on it and waves it from side to side.

The nymph is dark brown, lighter beneath, with a pair of circular pads on either side of the 7th abdominal segment which carry thick moveable brushes of long brown and white hairs and a pair of membranous wax plates near the brush-pads. The quantity of hairs on the anal pad increases with each nymphal moult. Sensory pits are present on the thorax and spines on the apex of the tibia of the 3rd leg which also increase in number with the successive instars. The full-grown nymph is about 6·5 mm. long with anal brushes 10 mm. long. The adult leaf-hopper, 8–12 mm., is very variable in colour and markings in each sex but the female is generally yellowish, greenish or reddish with the forewings olivaceous green to straw-coloured with pale spots and fasciae and the legs purplish-red; and the male is brown to testaceous with the forewings pale to dark brown, slightly speckled and bearing 2 black spots in the apical area, and the legs red to fuscous. There are no anal brushes of hairs in either sex. The nymphal period lasts for 95 to 108 days (average 101 days) thus giving a life-cycle from egg to adult of 119 days. The adult may live for 2 months. In the sandal forests of Madras, where the climatic conditions are not marked by great extremes of temperature, 3 generations occur each year. The first generation is marked by an increase in the numbers of bugs from March to May, followed by a fall in June and July. Thence the population

and foliage of *Acrocarpus fraxinifolius*, *Aegle marmelos*, *Cassia occidentalis*, *Erythrina indica*, *E. lithosperma*, *Lannea grandis*, *Michelia champaca*, *Santalum album*. The adult, 1 inch, is dark brown to black; the hind legs have the femora enlarged and thickened and in the male furnished with a large tooth. It can eject a spray of odorous irritating liquid from a protrusible organ at the end of the abdomen. Eggs are laid in a string of 10–20 along a stem of the plant; the egg is a cushion, U-shaped in section, 2·5 mm. long. Hatching takes 6–10 days in June–July. The newly hatched nymph is black and resembles a *Cremastogaster* or *Camponotus* ant; the brood feeds gregariously during the 1st instar which lasts 3 to 5 days. In the 2nd instar the fore tibiae are enlarged and the nymph resembles a young mantis; there are 5 nymphal stages and probably 3 or 4 generations a year. Hingston's essay on the protective adaptations of this species describes an interesting aspect: "First we have camouflage or harmonization. The eggs blend with the supporting stem. Then comes deceit or simulation. The insect lifts its abdomen to suggest a sting, and grows a pair of flattened front legs that give the impression of cutting blades. At the same time another device develops, the drapery it manufactures of blackened leaves that blend both with its colour and shape. With growth these and other ruses cease to be effective. Then the creature takes to dropping to ground Also it develops two pores on its back from which it squirts an offensive juice. But its wings grow and cover these pores. Consequently it develops another machinery, a telescope at the end of its abdomen from which issues a nauseous jet. One last touch completes the system. This is the warning flash of colour, the red signal of danger which illuminates its flight".

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of nymphs and adults steadily increases until it reaches its maximum for the year in September and October. The third or cold weather generation extends from December to February and is the least populous of the three.

Economic importance: The feeding of this leaf-hopper on *Santalum album* and other trees checks the growth of the new shoots and if the attack is prolonged and heavy the leaves are shed and the young shoots die back. It is one of the group of sap-suckers responsible for stagheadedness and thin crowns and is probably one of the factors lowering the resistance of sandal to the spike disease, but is not a vector.

Chatterjee N. C., 1933, ***Ind. For. Rec.***, XVIII, xiii, pp. 26, pls. i, ii, The life-history and morphology of Eurybrachys tomentosa Fabr., Fulgoridae (12).

Flata ferrugata. This pale-green-winged leaf-hopper occurs throughout India on various trees including *Santalum album*, *Tectona grandis*, *Webera corymbosa* and in the south breeds on sandal. The female makes a fine slit in the epidermis of young shoots and inserts an egg; a few eggs may be laid close together and the site of oviposition becomes swollen and eventually splits forming an elongate scar. The total life-cycle from egg to adult takes about 117 days and there are 3 generations in a year in south India, where the insect is most abundant during June–August and less during January–March. It is scarce during April–May and September–November when the southwest and northeast monsoons occur. The adults often assemble in large numbers on foliage or shoots.

Chatterjee N. C. and Bose M., 1934, ***Ind. For. Rec.***, XIX, vii, pp. 11-13, 2 figs.

Phromnia marginella. The nymphs assemble in abundance on the leaves and stems of *Casearia tomentosa* and *Elaeodendron glaucum*. Each nymph bears clusters of numerous white waxy filaments which almost double its apparent bulk and make a conspicuous white patch. A tree affected by a colony of *Phromnia* is visible at a great distance by reason of the thick white 'snow' over its foliage and stems. The nymphs excrete a sugary fluid copiously which hardens to a white glazed layer.

Ricania fenestrata occurs in the south of India on *Canthium didymum*, *Santalum album* and *Zizyphus oenoplia*. The eggs are laid partly embedded in the shoots of *S. album*. The nymphs are whitish-green with two cottony anal brushes which are shed immediately if the nymphs are touched. It moults 4 times before becoming adult and has a total life-cycle of 90 to 100 days—egg stage 21–23 days, 1st nymphal stage 17–20 days, 2nd 17–18 days, 3rd 18–20 days, 4th 19–20 days in south India.

Chatterjee N. C. and Bose M., 1934, ***tit. cit.***, pp. 9, 10.

Salurnis marginellus. A widely distributed species occurring on bamboo and various trees, breeding on *Santalum album*. The

female cuts a slit in the bark of young shoots and inserts an egg; the place of oviposition is marked by a slight swelling. The nymph is greenish-white with longitudinal lines of orange and green on the back and of white on the sides of the body, and has a pair of white cottony anal brushes. There are 5 nymphal stages with a total life-cycle of 100–120 days; egg-stage 18–21, 1st nymphal stage 16–22, 2nd 16–19, 3rd 18–20, 4th 17–21, 5th 20 days.

Chatterjee N. C. and Bose. M., 1934, *tit. cit.*, pp. 10, 11.

Sarima nigroclypeata is common in the sandal forests of south India on *Albizzia amara*, *Dodonaea viscosa*, *Erythroxylon monogynum*, *Lantana camara*, *Pterolobium indicum*, *Santalum album*, *Scutia indica*, and *Webera corymbosa*.

Life-history: Eggs are laid singly, or rarely in small clusters, on the bark of shoots, at the junction of the leaf and shoot, on the petiole, the leaf and the sprouting bud. Freshly laid eggs are white oval specks the colour of which changes gradually to yellow and pinkish. Hatching takes place in 17 to 25 days, or 3 weeks on an average. The newly hatched nymph makes its way to the young leaves or opening buds, punctures the surface-tissue and sucks the sap. It passes through 5 nymphal instars, feeding during the first 2 instars on the foliage and succulent shoots, and during the 3 later instars on the stouter shoots of both healthy and spiked plants. The remains of the digested sap are ejected from the tip of the abdomen as a fine sugary spray, which falling on the foliage coats it with a shining glaze. A sooty mould eventually grows on this film. The nymphs are at first pinkish-brown with pink spots on the pronotum and spots or bands on the dorsal abdominal segments, and later in life become darker brown or black with paler areas. Nymphs of all instars have a pair of kidney-shaped white pads on the anal segment from which arise bundles or brushes of waxy filaments in colour white banded with black. These filaments are most conspicuous in the 3rd instar and most numerous in the last instar. The full grown nymph is 3¼–4½ mm. long with brushes 5–6½ mm. long. The adult leaf-hopper is brownish with black speckling and brown striped yellow legs; length 4–5 mm. All stages of the insect are active and readily jump when disturbed. Flight is weak. The nymphal period lasts for 82 to 118 days (average 100 days) thus giving a life-cycle from egg to adult of about 120 days. The adult may live for 3 months. There are thus 3 generations a year, which do not vary much in length in the climatic conditions in the sandal forests of south India, and all stages of the insect occur simultaneously throughout the year. It is most abundant from June to September, and least abundant round about April and November.

Economic importance: This species when feeding on

sandal foliage and shoots seriously checks the growth; if its attack is prolonged and severe the foliage may be shed entirely and the young shoots and twigs may be killed back. It is one of the group of sap-sucking insects responsible for stagheadedness and thin crowns, and one of the factors lowering the resistance of the tree to spike disease.

Chatterjee N. C., 1933, *Ind. For. Rec.*, XVIII, XII, pp. 1-26, pl. 2, The life-history and morphology of Sarima nigroclypeata Mel.
Chatterjee N. C. and Bose M., 1934, *Ind. For. Rec.*, XIX, VIII, pp. 7-8.

Tambinia verticalis occurs on *Canthium didymum*, *Dodonaea viscosa*, *Santalum album*, *Webera corymbosa*, *Zizyphus oenoplia* in south India. Eggs are laid singly partly embedded in the bark of suberised shoots, in succulent shoots, and in the petiole and midrib of leaves of *Canthium didymum*. A female lays about 40 eggs. The 1st stage nymph is light orange mottled with darker shades; older nymphs are greenish-white with orange stripes and spots, and bear 6 translucent stiff wax bristles which are 2 to 3 times longer than the body and radiate from the anal segment. *T. verticalis* passes through 5 moults and has a total life-cycle from egg to adult of 95 to 120 days in south India–egg 18–21, 1st nymphal stage 15–18, 2nd 16–20, 3rd 15–21, 4th 16–21 and 5th 15–20 days. The adult leaf-hopper lives for about 2 months. It is most abundant during January and February.

Chatterjee N. C. and Bose M., 1934, *tit. cit.*, pp. 5, 6.

JASSIDAE

LEAF-HOPPERS (also termed Cicadellidae) form a large family of sap-suckers, rather similar to Cercopidae in shape, many species of which are pests to agriculture. Because of their cryptic or inconspicuous coloration as well as their habit of sheltering by day in low vegetation and of feeding actively after dusk, those species which attack forest trees have not been particularly investigated so that very few have been recognised as pests. Only the jassid fauna of *Santalum album*, which amounts to over 50 species, has been intensively studied. Since the family Jassidae includes several species proved to be vectors of the virus diseases of plants (mainly of the 'yellows' group) it received special attention from an early stage in the entomological investigations on the spike disease of sandal that have been undertaken by several agencies since about 1930 in Mysore, Coorg and Madras. Over 20 species have been tested for the transmission of this disease and after 10 years of research only one species, *Jassus indicus*, has been incriminated.

The normal type of life-cycle of arboreal jassids permits about 3 generations a year, usually with a long nymphal period, but the adult life is also much prolonged. Eggs are laid in slits in plant-tissues [fig.] and the nymphs, like the adults, feed by sucking the sap from new growth of the food-plant. For some species the

oviposition-period is restricted to short seasons. Several species attacking agricultural crops multiply in a series of short life-cycles of 2–4 weeks duration. The taxonomy of the family has been covered by Distant and Pruthi.

LITERATURE ON JASSIDAE:

Beeson, 1933, *Ind. For. Rec.*, XVII, ix, pp. 1-6, Entomological investigations on the spike disease of sandal (2). Historical note.

Distant W. L., 1907-1918, *Fauna Brit. Ind.*, Rhynchota, IV, pp. 157-419, figs. 106-255. — VI, pp. 217-240, figs. 160-177. — VII, pp. 1-109. figs. 1-65, Jassidae.

Dover C. and Appana M., 1934, *Ind. For. Rec.*, XX, i, pp. 25, pls. i-iii, Studies in insect transmission (20).

Pruthi H. S., 1930-1936, *Mem. Ind. Mus.*, XI, pp. 1-131, figs. 141, pls. ix, Studies in Indian Jassidae, parts i-iii.

— 1934, *Ind. For. Rec.*, XIX, vi, pp. 30, figs. 8, pl. i, Jassidae of sandal (14).

Rangaswami S. and Griffith A. L., 1940, *Ind. For. Rec.*, Ent., VI, No. 4, pp. 85-196, pls. i-xii, Further studies in the spike disease of sandal (35).

Acropona walkeri feeds commonly on *Canthium didymum*, *Pterolobium indicum*, *Santalum album*, *Webera corymbosa* and *Zizyphus oenoplia* in south India. Dwarfed bunched foliage is produced on *Santalum album* after prolonged feeding by this species (figured by Dover and Appana, 1934, *tit. cit.*, pl. iii, no. 1).

Bythoscopus indicus, a widespread and probably polyphagous species, feeds on *Santalum album* in south India where it is very abundant in July–September, decreases from October–March and is scarce in April, May. There are probably 2 or 3 generations a year. It has been tested as a vector of spike with negative results.

Pruthi H. S., 1934, *tit. cit.*, pp. 8-10, fig. 2.

Idiocerus atkinsoni, I. clypealis, I. niveosparsus Under the collective name "mangohopper" are included 3 species of *Idiocerus* the relative proportions of which vary with the locality and the season from year to year. In south India the most injurious species is *I. niveosparsus.* In Bombay Presidency *I. clypealis* is considered to be the most harmful species. Ecologically they are of interest because of the very short nymphal period and long imaginal period.

Life-history: In the south as soon as the flower-buds of the mango begin to form the adults become active and lay eggs in the tissues of the inflorescence, chiefly in the florets and their stalklets. The egg-period lasts 4–7 days and the nymphal period 8–10 days with 4 moults. The total length of the life-cycle from egg to adult is 12 to 17 days. In the Konkan, Bombay, the life-cycle of each of the 3 species is 15–19 days.

"The hoppers damage the mango crop in two different ways; firstly, by the heaviness of egg-laying physical injury is caused to the stalklets as well as the individual florets, so that they ultimately wither and drop. Secondly, the young ones, which

hatch in large numbers, crowd together thickly among the florets, and with their sharp sucking tubes, pierce the tissues of the flower panicles and drain their sap. The greater part of the juices thus sucked is, however, excreted after a certain amount of digestion, as droplets of a sweet fluid known popularly as the "honey-dew", and as this excretion, falling as it does, in severe cases of infestation, in an incessant and an almost audible drizzle may often-times be found covering not only the leaves and branches, but also the ground as a fairly thick incrustation, the heaviness of the drain on the resources of the plant, especially at the time of the setting of the crop, will be clearly apparent" (Rao). In years when the attack of the hopper is very serious, the amount of honey dew is so great that even the inflorescences do not set. In dry weather the honeydew forms a transparent shining yellow film; in wet weather it is invaded by sooty moulds.

After the fall of the blossoms and setting of the fruit the mango-hoppers attack the young leaves and leaf-buds. In some years two or more broods may occur during the blossoming season and another brood occurs with the flushing of the leaves and the nymphs feed on the leaf-shoots. A 4th brood may appear if an other flush of leaves occurs during the monsoon, but ordinarily the adult bugs pass over the rains and cold weather frequenting other species of trees, e g., *Bauhinia purpurea*, *Ficus retusa*, *Gmelina arborea*, *Lantana aculeata*, and *Morus indica*, Wagle states that *I. atkinsoni* and *I. niveosparsus* breed 3 times a year in June, October and January–March, and *I. clypealis* breeds only once in January–March (in the Konkan, Bombay), and all 3 species pass the intervening periods in the adult stage.

Rao Y. R., 1930, *Agr. Journ. Ind*, xxv, i, pp 17 25, The Mango hopper problem in South India

Wagle P V, 1928, *Mem Dept Agr Ind*, Bot Ser., xv, pp. 219-249

— 1934, *Agr. and Livestock Ind*, iv, pp 176-188, pl 2, Mangohoppers and their control in Konkan.

Jassus indicus occurs throughout India in cultivated land and fairly commonly in forests, frequenting several species of trees and lantana but its chief food plants have not been determined. It feeds on *Santalum album* in South India and has been under investigation for some years as a vector of the virus of spike disease. In 1938 suspicious and in 1940 typical symptoms of spike were produced in healthy sandal subjected to *Jassus indicus* that had previously fed on disease-masking sandal in experiments conducted by the Silviculturist, Madras, confirmation of the transmission of the disease is being obtained by grafting leaves from the infected trees on healthy ones (see *lit. cit.*, 1940, pl. xii, fig. 4, for photograph of the suspected plant). The average period from infection to manifestation of the disease is about 7 months, in the case of artificial infection by grafting the disease may be manifested in 4½ months. After the disease is manifested

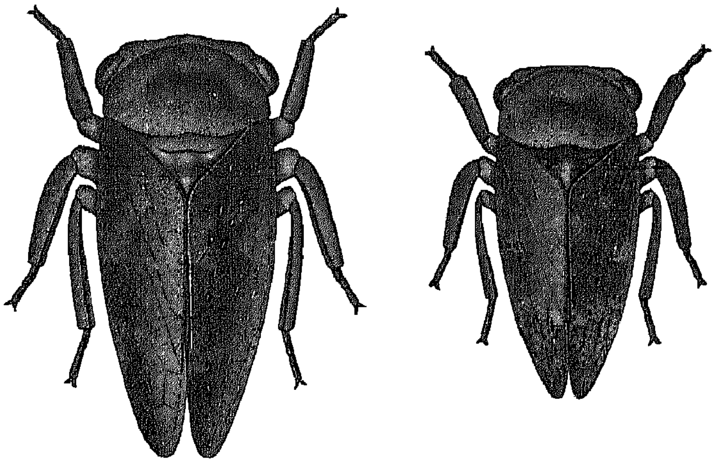


Fig. 191. Moonia albimaculata, female (left). male (right), 5-6 mm.

in the new flush of foliage the tree lives on an average about 15 months but the period depends on the size and age of the tree, and the host-plant; a spiked sandal does not recover. For full details of the etiology of spike disease and the entomological investigations of the period 1930-1940 see references to literature page 763 Beeson, 1933, Dover, 1932; Dover and Appana, 1934; Rangaswami and Griffith, 1940. There are probably 3 generations a year in south India; adult life lasts about 3 months and the population on sandal is high in February, June, July (maximum) and October.

Pruthi H. S., 1934, *Ind. For. Rec.*, xix, iv, pp. 19-21, fig. 5,
Rangaswami S. and Griffith A. L., 1940, *tit. cit.*, vi, No. 4. pp. 125, 126, 183, pl. xii, fig. 4.

Ledra mutica feeds on *Albizzia amara* and *Santalum album.*

Ledropsis rubromaculata, 11-13 mm., feeds on *Acacia catechu*; the flattened scale like nymphs completely cover the shoots in April-June.

Moonia albimaculata [fig. 191] occurs throughout the year and is most abundant in May-July and December-January on *Santalum album* in south India. Numerous experiments have been made to test the ability of this species to transmit spike disease. In 1932 Dover and Appana (1934) obtained suspicious symptoms which agreed in cytological, biochemical and biometric characteristics with those of spiked trees (see *tit. cit.*, 1934, pl. ii, fig. 3, for photograph of the suspected plants). These symptoms were not transmissible to healthy plants by leaf-grafting and some of the suspected plants recovered after remedial treatment. Similar spike-like characters were produced by *M. albi*-

maculata in 1937 in experiments done by the Silviculturist, Madras (*tit. cit.*, 1940, pp. 124, 125, pl. xii, fig. 1) but they were not permanent or fatal. These deceptive symptoms are considered to result from the mass-feeding by *Moonia* combined with the death of the host of the sandal.

Dover C. and Appanna M., 1934, *Ind. For. Rec.*, xx, i, pp. 15, 22-24, pl. ii.
Pruthi H. S., 1934, *tit. cit.*, xix, iv, p. 11, fig. 3, pl. i, figs. 3, 4.
Rangaswami S. and Griffith A. L., 1940, *tit. cit.*, vi, No. 4, pp. 123-125, 184, 185, pl. xii, fig. 1.

Neodartus acocephaloides, a widespread species, frequenting trees. In south India on *Santalum album* adults occur throughout the year and most abundantly from February–July. There are probably 2 generations a year. It is not a vector of spike disease.

Pruthi H. S., 1934, *tit. cit.*, pp. 15, 16, fig. 4.

Nephotettix bipunctatus, a widespread oriental species, and one of the rice leaf-hoppers, is known in some parts of India as 'Greenfly' or 'Diwali-fly'. It is attracted to light in such great numbers as to be an intolerable nuisance in houses; when swarming is at its height the accumulation of dead bodies near powerful lights is remarkable. Together with other species it breeds in rice-fields during the monsoon, the life-cycle taking 3 or 4 weeks; the adult lives through the winter and further generations are completed in the hot weather where suitable breeding-material (grasses, etc.) is available.

Misra C. S., 1920, *Mem. Dept. Agr. Ind.*, Ent., v, pp. 207-239, pls. xx-xxiii, The rice leaf-hoppers (Nephotettix bipunctatus and N. apicalis).

Petalocephala nigrilinea [fig. 192] occurs in south India, Ceylon and Burma feeding and breeding on *Canthium didymum*, *Dodonaea viscosa*, *Erythroxylon monogynum*, *Lantana aculeata*, *Santalum album*, *Scutia indica*, and *Webera corymbosa*.

Life-history: The female oviposits 10–20 days after the first pairing. A slit is cut with the ovipositor mostly in green succulent shoots, but also in suberised shoots of about the thickness of a pencil. The main slit is ½ to ¾ rs of an inch long with smaller lacerations near by. The eggs are inserted obliquely to the axis of the shoot in a row of 7 to 9 with their long sides touching [fig. 192 *a*, *b*, *c*].

Instalments are laid at intervals of 5 to 7 days to a total of about 120 eggs which hatch in 23 days in August–September and require 30 days in December–January (mode 27 days). The primary nymph when it emerges from the eggshell is enclosed in a membrane which ruptures immediately emergence is completed. There are 5 subsequent nymphal instars; a moult takes 20 to 30 minutes. The total life-cycle from egg to adult varies from 108 to 150 days, the average being 130 days. Nymphs of all stages suck the sap of the leaves. The adult leaf-hopper [fig. 192] has a maximum life of 3½ months and feeds on green or suberised shoots. There are thus 3 generations in a year and the insect is

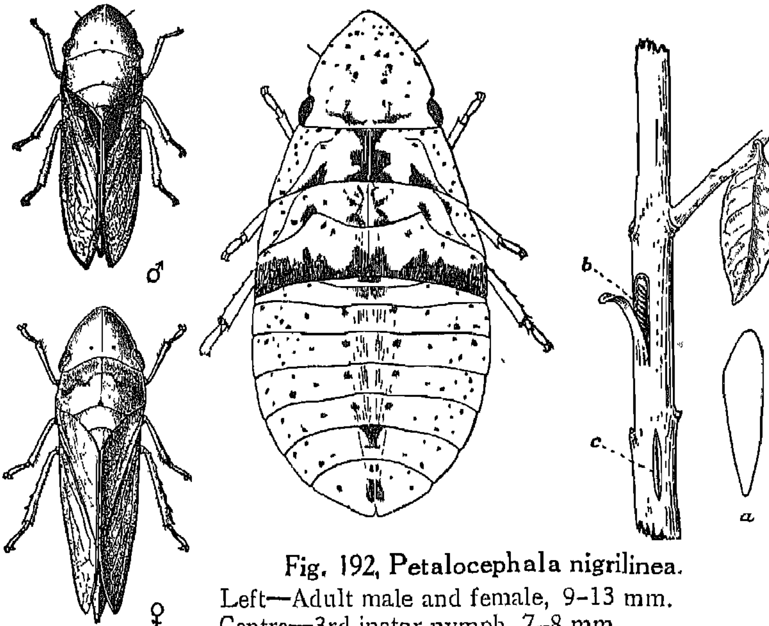


Fig. 192, Petalocephala nigrilinea.
Left—Adult male and female, 9–13 mm.
Centre—3rd instar nymph, 7–8 mm.
Right—Shoot of Santalum album showing (b) eggs laid in bark, (a) enlarged egg and (c) scar left after hatching of eggs.

active in all stages at all seasons in south India. Its population is highest during February-April and again during August-October. Between May and July when the south-west monsoon is operating the population decreases, and the period November-January of the north-east monsoon produces a similar reduction. The colour and patterning of the nymphs and adults is extremely varied; the dimorphic forms might be mistaken for separate species. Nymphs in all stages are more or less transparent at the edge and as they rest closely pressed to the surface of leaves are difficult to detect [fig. 192, 3rd stage nymph]. Adults also rest with their bodies closely pressed to the shoots and when disturbed leap distance of a yard or two, or if a wind is blowing may be carried longer distances.

Economic importance: The feeding of large numbers of nymphs and adults of *P. nigrilinea* checks the growth of the plant. The foliage of *S. album* withers and falls and young shoots dry up If the shoots do not die the new flush is shortened and bunched and resembles spike. A 3-year old tree may be killed in 3 months and a seedling in 2 months, if heavily infested with this leaf-hopper. The wounds made in the shoots by ovipositing females form elongate oval scars; in thicker twigs the sub-

sequent growth causes the bark to crack exposing the wood in scars an inch long [fig. 192 c]. This species is largely responsible for the stag-headedness and thin crowns of sandal trees. Although it occurs abundantly on healthy and spiked sandal it has not been incriminated as a vector of the disease.

Chatterjee N. C., *Ind. For. Rec.*, XIX, IX, pp. 30, pl. i, ii, The life history and morphology of Petalocephala nigrilinea Walk.

MEMBRACIDAE

TREE-HOPPERS form a group of hopping sap-suckers, which feed on trees as well as herbaceous plants. Eggs are laid in double rows of slits in the epidermis of soft shoots which are permanently injured or killed by the lacerations. The nymphs on hatching remain in colonies feeding on the same shoot with the female parent; if disturbed they scatter by jumping but tend to reassemble. A sweet fluid is excreted from an anal tube which is attractive to ants which consequently attend upon and protect the tree-hoppers. The adults are remarkable for the grotesque fantastic shapes evolved mainly by modification of the thorax; none of the diverse designs have any evident advantage or function. Generations range from 2 to about 5 per annum.

LITERATURE ON MEMBRACIDAE:

Chatterjee N. C. and Bose M., 1937, *Ind. For. Rec.*, XIX, ii, pp. 1-8, figs. 1, 2, Membracidae and Cercopidae of sandal (13).

Distant W. L., 1907, *Fauna Brit. Ind.*, Rhynchota IV, pp. 1-78, figs. 1-64, Membracidae.

Funkhouser W. D., 1922, *Rec. Ind. Mus.*, XXIV, ii, pp. 323-329, New records and species of Membracidae from India.

— 1933, *Ind. For. Rec.*, XVII, x, pp. 10, Membracidae of sandal (3).

Coccosterphus tuberculatus, 3 mm., occurs in Ceylon and south India on *Albizzia amara*, *Barringtonia acutangula*, *Erythroxylon indicum*, *Pterolobium indicum* and *Scutia indica*. Under trial as a vector of the spike disease of *Santalum album* it has produced suspicious symptoms (illustrated by Rangaswami and Griffith, 1940, *Ind. For. Rec.*, Ent., VI, No. 4, p. 126, pl. xii, fig. 3); grafting tests from the suspected plant gave negative results. Eggs are laid in compound slits on young shoots. The life-cycle takes 3-4 months and there are 3 or more generations a year in south India with maximum abundance in January, February and August. Adults live for 10 or 11 weeks

Gargara mixta and **G varicolor**, 5 mm., widespread species, are injurious to *Dalbergia sissoo*. Eggs are laid in double rows on the current shoots; the nymphs are gregarious and suck the sap. The oviposition-scars cause the nodes and leaf bases to swell and dry up. In shisham plantations they are abundant from April to June.

Otionotus oneratus, 6 mm., a widespread species in India and Ceylon, is abundant on *Santalum album* especially from September to March (maximum in November and again in

February) and is scarce in May–August. There are 2 or 3 generations a year. It does not transmit the spike disease of sandal.

Chatterjee N. C. and Bose M., 1933, *tit. cit.*, figs. 1, 2.

Oxyrachis tarandus, 7–10 mm., found also in Africa, feeds on *Acacia arabica*, *A. catechu*, *A. siamea*, *Albizzia lebbek*, *A. procera*, *Dalbergia latifolia*, *Phyllanthus emblica* and *Tamarindus indica* in India. Eggs are laid in close herring-bone or V-slits cut by the ovipositor in the thin bark of shoots. The egg is 1·5 mm. long and has at one end a fine hair-like hook. There are 4–13 eggs in each arm of each V making a total of 100–250 eggs laid in one patch. After they have hatched a broad oval scar is left which distorts or stunts the growth of the shoot or kills it [fig. 193]. The scar is used by the moth of a bark-boring caterpillar as a site for oviposition. The nymphs of *O. tarandus* are gregarious and feed on the same shoot with the adults; the abdomen ends in a telescopic tube fitted with an extensile crimson organ that emits honeydew. Feeding nymphs are attended by *Camponotus* and *Cremastogaster* ants which drink the honeydew. Ovipositing broods of *O. tarandus* occur throughout the monsoon. Eggs take some weeks to hatch and the nymphs pass through 5 stages before maturing. The life-cycle takes 6 weeks in April–September and 8 weeks during October, November and is longer through the cold season in north India, where there are 5 generations a year.

Chatterjee N. C., 1914, *Ind. For.*, XL, pp. 75-79, pls. iii, iv, A note on Oxyrachis tarandus Fabr.

PENTATOMIDAE

STINK BUGS, by which name the PENTATOMIDAE are usually known, is not exclusively descriptive since nearly all Hemiptera have glands that produce scents unpleasant to human nostrils. The adults are easily identifiable by the large triangular or shield-like scutellum. This very large family is composed chiefly of sap-suckers but many species are predators throughout life sucking the blood and body-fluids of other insects, particularly caterpillars. The carnivorous species are able to supplement their diet with plant sap and in the 1st instar often feed wholly on the sap of those plants that are eaten by their lepidopterous prey. The barrel-shaped eggs are laid in compact groups on plants and the nymphs hatch by pushing off a circular lid. Successive nymphal instars are often coloured and patterned differently and the adult displays yet another colour-pattern. Life-cycles vary from about one to seven months. In India the pentatomid fauna of only one tree, *Santalum album*, has been specially studied; sandal is frequented by 77 species one of which produces symptoms deceptively like spike.

LITERATURE ON PENTATOMIDAE:
Chatterjee N. C., 1934, *Ind. For. Rec.*, XXIX, pp. 31, fig. 1, Pentatomidae of sandal (24).
Distant W. L., 1902-1916, *Fauna Brit. Ind.*, Rhynchota, I, pp. 1-330, figs. 1-201, — IV, pp. 420-466, figs. 256-273 — VII, pp. 110-151, figs. 66-74, Pentatomidae.
Rangaswami S. and Griffith A. L., 1940, *Ind. For. Rec.*, Ent., VI, No. 4, pp. 85, 196, pls. i-xii, Further studies in the spike disease of sandal (35).

Andrallus spinidens is predaceous on various species of caterpillars including *Prodenia litura* (Noctuidae).

Amyotia malabaricus is predaceous on *Myllocerus*, Curculionidae (beetles).

Antestia cruciata is a general feeder on shoots and fruits of *Canthium didymum*, *Citrus*, *Coffea*, *Lantana*, *Jasminum*, *Mangifera indica*, *Prunus* spp., *Pterolobium indicum*, *Santalum album*, *Schleichera trijuga*, *Webera corymbosa*, *Zizyphus oenoplia*. It sometimes swarms in very great numbers, over-running and destroying fruit and vegetable and cereal crops, appearing in abundance in November and remaining through the cold and hot weather until heavy rains kill it off. Eggs are laid in clusters (7–13) and the life-cycle lasts 30 days. The adult lives 2 months.
Chatterjee N. C., 1934, *tit. cit.*, XX, ix, p. 16.

Canthecona furcellata. Eggs are laid in close rows of 20 to 70 in a batch on the surface of a leaf. The egg is bucket-shaped, 1 mm. × 0·7 mm., closed by a flat circular lid along the rim of which are 12 short curved spines. The fresh egg is yellowish-grey and later turns green and golden-yellow. Incubation (in October) lasts for 8–9 days. The nymphs are black or deep bluish-green with bright scarlet markings which vary much in size and arrangement from stage to stage of the 5 nymphal instars. The nymphal period (in October) is 21 days. The 1st instar nymphs feed gregariously on the sap of leaves and on drops of moisture. In the instars from the 2nd onwards the insect is carnivorous, feeding on caterpillars and pupae of Lepidoptera, notably *Hyblaea puera* (Hyblaeidae), *Hapalia machaeralis*, *Margaronia laticostalis*, *Nephopteryx rhodobasalis* (Pyralidae), *Plecoptera reflexa* and *Prodenia litura* (Noctuidae) and also on the larvae of *Calopepla leayana* (Chrysomelidae). Several, e.g., 20, young bugs cooperate in subduing a caterpillar much bulkier than themselves; 1–2 caterpillars suffice 10 young bugs for a day's food. The 4th stage nymph can dispose of half a *puera* or *machaeralis* larva per day, while a single 5th stage nymph sucks one caterpillar dry daily on an average. The adult *furcellata* is about 1½ cm. long, brown with light speckling and the legs yellow-banded. It is long-lived (to 70 days) and feeds at the rate of appoximately one caterpillar per day. When attacking prey much bulkier or stronger than itself it usually approaches from behind in order to stab the prey with its beak and allows itself to be dragged about by the struggling caterpillar until the

latter succumbs to the paralysing effect of the saliva that is injected in the wound. With the onset of the cold weather it becomes inactive and hibernates in sheltered crevices until the end of March (in Dehra Dun). Eggs laid in April produce adults in about 4 weeks. A second or more generations takes place between May and September. The last life-cycle of the year commencing in September is adult in about 40 days and the resulting adults hibernate giving a total life-cycle of about 190 days. It is estimated that the progeny of a single female laying 170 eggs could destroy 1,600 caterpillars in the nymphal stages and 5,000 caterpillars in the adult bug stage.

Coptosoma cribrarium, a widespread species, is a pest of cultivated Leguminosae and Compositae in India. The life-cycle lasts about 2 months in south India (egg 6, 1st instar nymph 8, 2nd 6, 3rd 9, 4th 9, 5th 10 days).

Ayyar T. V. R., 1933, *Agr. Dept.*, *Madras*, Bull. 34, p. 13, pl. i, fig. 5.

C. ostensum attacks *Butea frondosa* in south India causing defoliation in March, April. Five other species of *Coptosoma* occur on *Santalum album*.

Chrysocoris stockerus and **C. pulchellus** breed on *Lantana* and *Santalum album* and are commonest from April to September. The life-cycle lasts 6 or 7 weeks; eggs hatch in about 9 days.

Cyclopelta obscura sometimes swarms in large numbers on the young shoots of *Erythrina lithosperma* sucking the sap and causing the death of the shoots. The eggs are laid in broad bands on the shoots.

Cyclopelta siccifolia congregates on twigs in massed colonies in order to feed. The position taken during feeding is usually with the head upwards towards the distal end of the shoot, but a colony may often be so crowded that the bodies of the bugs overlap. When disturbed the bug ejects a thin jet of watery fluid from the anus that causes intense irritation and inflamation of the human eye. The feeding-punctures appear as withered brown spots on the epidermis of the plant. The adult bug is about ½ to ⅔rs of an inch long, oval, very dark brown in colour, with the membranous areas of the forewings light brown; the nymphs are much lighter in colour. The insects have a strong pungent odour. Eggs are laid in longitudinal rows on the twigs of *Cajanus indicus*, *Erythrina indica*, *E. lithosperma*, *Moringa pterygosperma*, *Pongamia glabra*, *Sesbania aegyptiaca*. Hibernation occurs under stones.

Erthesina fullo frequents many species of trees in the Indian region. The life-cycle lasts about 5 weeks.

Halymorpha picus feeds on the pulp of fruits of *Lantana*; the life-cycle lasts about 40 days.

Halys dentatus occurs on *Acacia arabica*, *Albizzia lebbek*, *Casuarina equisetifolia*, *Lantana* and *Santalum album* and

other trees in the Indian region

Nezara viridula, a cosmopolitan polyphagous species, 12–16 mm., bright green in the adult stage, is a pest in India of agricultural crops and is not very abundant in forests but may assemble in large swarms. It is a proved vector of fungus diseases and boll rots of cotton. In trials as a vector of spike disease of *Santalum album* in 1938 it produced suspicious symptoms which completely resembled spike but were not transferable by grafting tests. The *Nezara* fed plants slowly returned to normal; the symptoms were not connected with the ill health or death of the host-plants and recovery was not obtained by providing new hosts and manuring.

See Rangaswami and Griffith, 1940, *tit. cit.*, VI, 4, p. 125, pl. xi, figs. 2, 3, for illustrations of the affected sandal; and Chatterjee, *tit. cit.*, XX, IX, p. 19 for references to literature.

Ochrophara montana feeds on the seeds of bamboos while they are forming on the flowered branches and after they have fallen to the ground. Owing to the rapidity of its increase with the abundant food-supply that results from the wholesale flowering of bamboos, countless swarms of bugs are produced. One such epidemic in 1917 in Mysore is described—"I found the whole hill (on 1st July) one mass of these insects; every tuft of grass held thousands if not millions of them; as we walked along they rose in clouds . . . . . From a short distance the coffee estate appeared to have suffered from a cyclone, the shade trees, *Grevillea robusta*, had their branches bent or broken and lying about all over the place . . . the leaves and branches were laden with insects......branches thicker than one's arm, which would have supported a man without breaking, were snapped off". Similar epidemics have occurred in Chanda, C. P., in Kanara, Bombay and in Coorg; and in West Salween, Pegu Yomas, Burma, where acres of the forest floor were carpeted with the bugs. The exhaustion of the food-supply or the occurrence of heavy rain kills off the swarms. The adult insect is coloured, like many other pentatomids, ochraceous-yellow and somewhat thickly speckled, but has the pronotal angles either obtusely rounded or provided with a short acute spine directed forwards.

Fletcher T. B., *Agr. Res. Inst.*, Bull. 89, 1919, Second hundred notes on Indian insects, p. 84.

Plautia fimbriata is a widely spread species attacking, among other food-plants, the fruits of *Lantana* on which it is common in south India.

Poecilocoris latus is the Tea Seed Bug, attacking the fruit in all its stages from the flower up to maturity.

Andrewes E. A., 1930, *Quart. Jl. Ind. Tea Assoc.*, i, p. 15, The tea seed bug.

Scutellera nobilis occurs on *Casearia tomentosa*, *Dodonaea viscosa*, *Phyllanthus emblica*, *Santalum album* and agricultural crops.

Tessarotoma javanica, a large brown bug, 25–30 mm., sucks the top shoots of *Butea frondosa* and *Schleichera trijuga*. It may become a pest in lac plantations during May to September. For control measures see Part Two.

Urostylis fumigata breeds on *Magnolia pterocarpa*, *Michelia oblonga* and *Talauma hogdsoni*. **U. pallida** on *Quercus incana*.

Urostylis punctigera, The Champ Bug

The food-plants are Magnoliaceae: *Magnolia pterocarpa*, *Manglietia insignis*, *Michelia champaca*, *M. excelsa*, *M. kingii*, (=*M. montana*), *M. oblonga*, *Talauma hodgsoni*, in Bengal and Assam. The adult, 9–11 mm., is yellowish-green with dark spots or punctures on the pronotum, corium and scutellum; the 5-segmented antennae are very dark. In the male the 8th abdominal sternite is notched at the sides and middle so as to form 3 processes; in the female the 8th sternite is small and its posterior margin is produced at the angles and fringed with short hairs.

Life-history

Oviposition: Pairing begins about 2 weeks after the last nymphal moult and may be deferred for a month during the heavy rains of June–August. Oviposition begins 4 or 5 days later. Eggs are laid on young leaves in 2 parallel rows in a mass of glutinous yellow secretion, each egg taking about 3 or 4 minutes to fix in position; the egg-mass contains 15–30 eggs (average 19). One female may lay 450 eggs (average about 250) in 30 separate egg-masses; the oviposition-period is ordinarily between 1 and 3 weeks but may extend to 5 weeks in March, April. During the premonsoon period adult bugs may live 9 weeks and during the monsoon, June to September, a life of 6 weeks is possible. Eggs hatch in 2 to 7 days at temperatures of 82°–74° F. The 1st instar nymph after hatching is not mobile and remains for 1–5 days on the egg-mass without feeding until the first skin is moulted. There are 5 nymphal stages.

Life-cycle: In Bengal-Assam there are 5 generations a year, the 1st beginning in March with a life-cycle from egg to adult of 33–50 days. The 2nd in May–July, 3rd in July–September and 4th in August–October develop within similar limits and the 5th in September–January is longer, taking 37–60 days in the earlier broods and 60 to over 100 days from eggs laid at the end of October and later. The adults of the 5th generation hibernate gregariously in dry curled leaves on the tree and rarely in debris forming the soil-cover, and live until March or April: those that begin hibernation in October may last for 190 days and those of January for 110 days. Occasionally they leave the shelters and feed on sap or water.

The following synopsis summarises the duration of the various stages:—

Stage	Egg	1st	2nd	3rd	4th	5th instars	Total life cycle
Range (days)	2-7	1-5	3-5	5-14	4-28	9-78	24-147
Mode (days)	4-5	3-4	6	6-7	7-8	19	42-52

Feeding-habits: On *Michelia champaca* nymphs suck the sap of newly formed leaves and soft shoots. In the 2nd and 3rd instars they feed exclusively on leaves, usually from the underside along the midrib; 4th and 5th instar nymphs feed on the petioles, soft shoots and older shoots with green epidermis and are unable to pierce hardened bark. In the early stages of an attack at the beginning of the season nymphs are crowded on the terminal foliage of the leading shoot and the uppermost branches of a tree which are drained of sap and wither. As the nymphs grow older and the new growth of the plant is exhausted they converge towards the thicker part of shoots and the main stem and concentrate near the whorls of shoots and round the stem. The adult prefers to suck petioles and green shoots but can feed on the thicker parts of lateral branches and the main stem of young trees. Because of its size and longer life the adult is able to cause more damage in sum than a nymph.

A young champ leaf on which *Urostylis* has fed soon wilts and crinkles. Older leaves show brown spots 1-3 days after being punctured; a brown spot appears first on the lower surface and spreads to the upper surface and adjacent spots coalesce to form a brown patch which ultimately turns white except at the edge. Leaves of which the petioles are sucked by 4th and 5th stage nymphs and adults turn yellow and fall. An attacked shoot shows brown patches and bands just below the epidermis, completely girdling it or killing it partially lengthwise. Under mass-attack young trees of *M. champaca* lose their leaders and laterals or die back to ground-level. Older trees to an age of at least 25 years have the crown and uppermost portion of the bole killed for a length of about 15 feet from the apex or to a diameter of 3 inches. One-year old plants can be killed in 12-14 days by the work of 30-40 nymphs and adults. Two-year old plants succumb to twice as many bugs. Three-year old plants resist 300-400 bugs for 3 weeks. The minimum number of bugs needed to kill 4 to 5-year old trees in a month is about 1,500. Poles which have partly died back usually recover and send out a new leader and the original dead top rots quickly and falls leaving a bayonet-topped bole. But before the new flush appears in the following season an attacked stand of poles appears to be completely killed.

The peculiarly severe effect of a mass attack of *U. punctigera* on champ trees is probably due to an inherent susceptibility on the part of this fast-growing tree and not to any virus or fungus disease injected by the bug. The wood of the dead

branches and stems is affected by fungi of the genera *Diplodea* and *Fusarium* under conditions which indicate they are not pathogenic. Where the stylets of the bug have penetrated into the pith of the stem the tissues collapse and disintegrate forming longitudinal cavities which are largest in the upper younger parts.

Economic importance

U. punctigera first appeared as a pest of pure champ plantations in north Bengal in 1927; in subsequent years it was discovered in most divisions in the Duars in plantations of all ages from 1 to 14 years old. By 1935 out of a total of 155 pure champ plantations 31 percent representing about 1/3rd of the area were seriously attacked. The age at which the crop was first attacked and the geographical distribution of the plantations attacked were more or less fortuitous; 8 percent remained immune from noticeable damage till the age of 8 and 63 percent remained immune till the age of 4 years; practically all were attacked before the first thinning. The invasion may have been determined by the occurrence of wild host-plants and the bridging of distances owing to the formation of new plantations. The highest incidence was developed in the foothills of Darjeeling and Kurseong divisions. At one period it was feared that pure plantations were doomed to total destruction by the bug and the annual programme of planting champ was therefore halted. It is now evident that within the boundaries of a plantation the damage done by *Urostylis* is frequently very localised and the infested area does not spread rapidly from year to year. This restricted and sometimes temporary intrusion of the pest into a pure crop is an important feature and an indication that permanent colonisation can be prevented and controlled by measures detailed in Part Two.

PSYLLIDAE

EGGS of the Jumping Plant Lice, or PSYLLIDAE, are laid singly and irregularly in the majority of species, scattered on the young foliage and buds, attached to the tissues by means of a stalk or process. The nymph is flattened and wing-pads develop in the later instars of which there are 5, the 6th being the adult stage. It usually feeds continuously on cell-sap at one spot and this results in a local malformation of the plant. The malformation takes a great variety of forms and is usually characteristic for each species of psyllid; it varies from more or less simple crumpling and distortion of a leaf to the production of chambers or cavities termed galls, each of which encloses one or more nymphs. Some species of nymphs produce a waxy secretion in the form of threads or dust, and also excrete a sweet liquid for which they are attended by ants. The nymphs of some gall-making species are abnormally modified.

Galls take the form of unilocular chambers, globular, conical, cigar-shaped or bladder-shaped on leaves and twigs, pit-galls in twigs in which the opening or roof is closed by the back of the nymph, rolls or twists of part or whole of the leaf, etc. The coalescence or agglomeration of several globular galls forms a multilocular mass, each cell of which contains its original nymph. Rolls or twists of the leaf-surface are usually inhabited by several nymphs. The young galls are brightly coloured, yellow, pink, red, mauve, brown, turning black or dark brown when they open and die.

The non-gall-forming species live freely on a leaf-surface and do not necessarily remain in one place. The number of generations varies from 1–11 per annum.

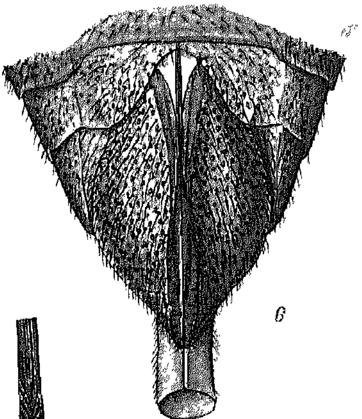
A heavy psyllid attack on mature or middle-aged trees should be regarded as an indication of reduced vitality. In seed beds and artificial regeneration areas psyllids can be very injurious. The large gall-making species which deform the new foliage and buds are the most injurious type; the free-living species with their larger number of generations per annum can be more injurious when weather conditions favour the infestation of new growth as fast as it is produced. As a rule heavy rain during the monsoon-season checks the multiplication of free-living forms.

LITERATURE ON PSYLLIDAE:
Crawford D L., 1912, *Rec. Ind. Mus.*, VII, V, pp. 419-437, pls. iii.
— 1924, *tit. cit.*, XXVI, vi, pp. 615-621, figs. 3, New Indian Psyllidae.
Laing F., 1930, *Ind. For. Rec.*, XIV, viii, pp. 166-175, Some records of Indo-Malayan Psyllidae.
Mathur R. N., 1935, *Ind. For. Rec.*, Ent., I, No. 2, pp. 71, pls. i, ii, On the biology of the Psyllidae (with a note by C. F. C. Beeson).
Rahman K. A., 1932, *Ind. Journ. Agr. Res*, ii, iv, pp. 358-377, pls. xxxvi-xl, Observations on the immature stages of some Indian Psyllidae.

Apsylla cistellata makes cone-shaped galls of overlapping scales or dwarfed leaves, $\frac{5}{8}-1\frac{1}{2}$ inches long, formed by malformation of the buds at the apex of the shoot or in the axil of the leaf of *Mangifera indica*. An average sized cone-gall may contain 30 nymphs. The galls exposed to greater sunlight mature first; the scales spread out from the central axis and leave the chambers open for the escape of the adult psyllids. The infestation of the buds starts in October and the nymphs winter inside the galls and mature in March–April. The insect is a pest in mango groves. Mathur, *tit. cit.*, pl. ii, fig 14.

Arytaina ramakrishnai forms galls on the leaves of *Chloroxylon swietenia*. **Arytaina** sp. feeds on the buds and foliage of *Albizzia procera*, causing the pinnae and rachis to be shed during May to July. Mathur, *tit. cit.*, pl. ii, fig. 15.

Fig. 193, Stem of a 3-year old Albizzia lebbek showing work of Oxyrachis tarandus; (a) scar produced by the egg-slits, (b) terminal shoot previously killed.



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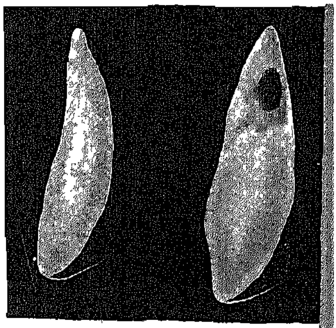

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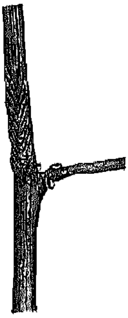

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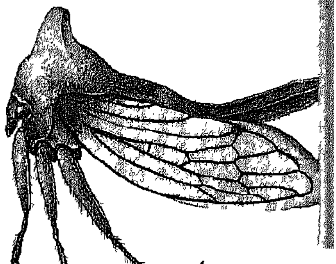

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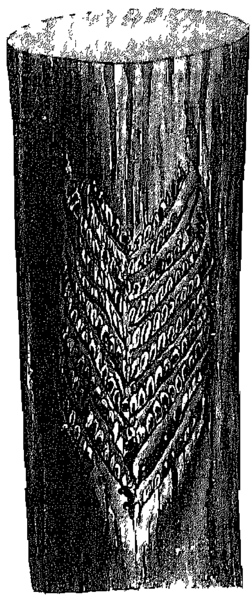

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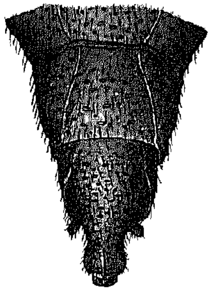

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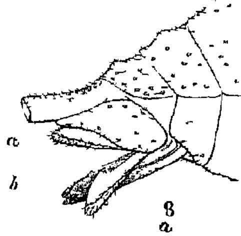

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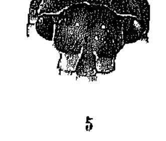

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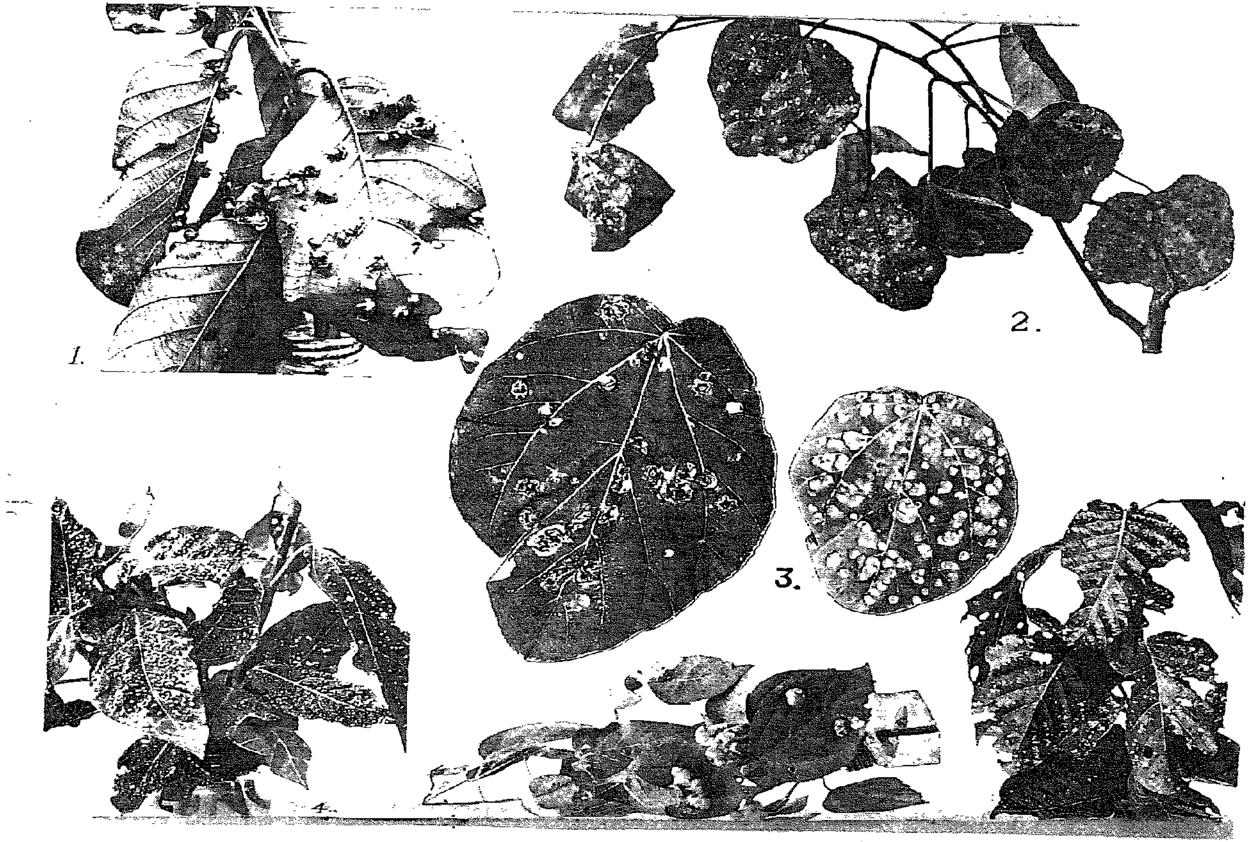
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Cerotrioza sp. galls the leaves of *Shorea robusta.* The nymphs suck at the midrib near the apex of the upper surface of top leaves of young shoots. The rib thickens and the blade of the leaf folds upwards to form a groove along the rib. The pest is most abundant after the monsoon season and decreases in numbers as the winter sets in. Mathur, *tit. cit.*, pl. ii, fig. 20.

Diaphorina truncata occurs on *Strychnos nux-vomica.*

Diaphorina sp. occurs on *Murraya koenigii* feeding on the leaves and young shoots which become deformed. The female lays 600 eggs in 35 days and these hatch in 3 to 5 days in hot weather and 9 to 14 days in February. There are 5 nymphal moults during a period varying from 10–35 days in hot weather to 65–80 days in winter. Activity lasts from February to November in north India with 9 generations in the year, varying from 14–40 days in hot weather and 70–85 days in cold weather. The adults alive in December do not oviposit but hibernate under leaves until February when eggs are laid. Mathur, *tit. cit.*, pp. 40–42.

Euphalerus vittatus feeds on the foliage of *Cassia fistula.* The eggs are laid mostly in grooves in the rachis and on buds and leaflets. The feeding of the nymphs causes the new growth to wilt or to become bunchy; top-shoots may be killed. Infestation begins in April or May from overwintered eggs. The first generation is completed in 20–25 days and 4 additional generations occur between May and August with a nymphal period of 14–30 days. Eggs are laid in August in crevices and other protected situations, which remain unhatched until the following April or early May. There are thus 5 generations per annum with a resting-period in the latter part of the rains and the cold weather in north India. Mathur, *tit. cit.*, pl. i, fig. 7.

Paurocephala sp. [fig. 194, No. 2] makes yellowish to brownish pit-galls on the leaf of *Kydia calycina.* There are probably more than 7 generations a year.

Pauropsylla beesoni [fig. 194, No. 1] makes small oval or spherical galls on the leaf of *Litsaea polyantha*, situated near the secondary veins, green or brownish, and dehiscing into 3 or 4 lobes. The eggs are laid singly on buds and on the under surface of soft leaves. A female may lay 300 eggs in 8 days. Hatching

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Fig. 194, Leaf-galls caused by Psyllidae.

No. 1—Blister-galls of Pauropsylla beesoni on leaves of Litsaea polyantha.

2—Pit-galls of Paurocephala sp. on leaves of Kydia calycina.

3—Leaf-galls of Pauropsylla sp. on Ficus roxburghii.

4—Pit-galls of Pauropsylla sp. on Ficus glomerata.

5—Blister-galls of Phylloplecta malloticola on leaves of Mallotus philippinensis.

6—Pit-galls of Phylloplecta sp. on leaves of Shorea robusta.

(The photographs are not uniformly reduced).

occurs in 3 to 5 days. The nymph feeds at one spot and becomes gradually enclosed in a unilocular gall about the size of a pea. Adjacent galls may coalesce and produce a chamber containing more than one psyllid. There are 5 nymphal moults during a period of 110–120 days in March–July and 250–260 days in July–March, making 2 generations a year in north India. The adults pair after emergence from the dehisced gall and die after a short while during which they feed on young foliage.

Mathur, 1935, *tit. cit.*, pp. 45-48, pl. I, fig. i.

Pauropsylla depressa makes galls on the leaves of *Ficus glomerata*. Each gall is a pointed sphere, its base projecting from the upper surface of the leaf, and its apex extending from the underside. They occur in clusters, or singly, and are pale green to reddish in colour. When badly affected the leaf withers and falls. Eggs are laid singly on buds and undersides of young leaves. A female may lay 300 eggs in 5 days, which hatch in 3 to 5 days. There are apparently 2 generations a year with adults in March and July.

Rahman K. A., 1932, *Ind. Journ. Agr. Sci.*, II, iv, pp, 365-367, pls. xxxviii, (nymphs).

Pauropsylla [fig. 194, No. 4] forms pit-galls on the leaves of *Ficus glomerata*. The pits are oval or circular, yellowish-green and protrude as small elevations or papillae on the opposite side. When the galls are very numerous the leaf curls up Eggs are deposited in clusters near the edges of leaves. A cluster may contain 350 eggs out of 800 or 900 eggs laid by one female during an oviposition-period of 3 weeks. Hatching takes place in 3 to 7 days. The nymph by feeding at a point forms a depression which becomes a pit. It moults in the pit and exudes a sugary liquid and a waxy secretion. The nymphal period lasts from 70 to 120 days (March to September) and 130 to 140 days (October to February). There are 3 generations in a year, the 1st commencing with the new foliage in February, the 2nd in May and the 3rd in October. Mathur, *tit. cit.*, pl. i, fig. 4.

Pauropsylla spondiasae rolls the leaves at the margins of *Spondias mangifera*. **P. tuberculata** makes galls on the leaf of *Alstonia scholaris* The gall is barrel-shaped with the rounded base projecting from the upper surface of the leaf and the major portion from the lower surface and bearing at the end an elongate slit which serves as an exit-hole for the nymphs. Many galls occur scattered on one leaf, about 20 on an average. After the escape of the adults the galls blacken and become woody.

Rahman K. A., 1932, *Ind Journ. Agr. Soc.*, II, iv, pp. 361-365, pl. xxxvi, (nymphs).

Pauropsylla [fig. 194, No. 3,] forms globular galls on the leaves of *Ficus roxburghii*.

Phacopteron lentiginosum makes large bladder-shaped, thin-walled galls on the leaves of *Garuga pinnata* and *Schleichera*

trijuga. The nymphs feed on the under surface of the mid-vein and secondary veins, which swell at the puncture and form an acorn-shaped gall which is at first concealed in the swelling. After the 2nd moult the nymphs pass into the interior of the gall which grows larger on the upper surface of the leaf. In a heavy infestation the leaf is completely transformed into what appears to be a bunch of grape-like or nut-like fruits which vary in colour from pale green to reddish-brown. Each gall contains several nymphs and flocculent secretions. The dry galls are dark brown and hard. The life cycle is probably annual. Mathur, *tit. cit.*, pl. ii, fig. 16 (literature).

Phylloplecta gardneri makes flattened, unicellular galls on the leaves of *Populus euphratica*, which are usually separate. yellowish to dark green, smooth and about 5 mm. × 4 mm. A leaf may carry 18 galls distributed on both surfaces. The gall opens by a pinhole, bounded by a rim and covered by a thin membrane which ruptures. The adults appear with the new foliage in January–February, and gall formation starts immediately. One nymph inhabits each gall and appears to pass a year in its development, moulting for the last time inside the gall. Mathur, *tit. cit.*, pl. ii, fig. 12

P. hirsuta galls the leaves of *Terminalia tomentosa*. Feeding by the nymphs at the margin of the leaf causes it to roll inwards longitudinally until the edge of the roll meets the upper surface of the midrib. The rolled parts of the leaf swell up and become coloured pink or mauve. The length or position of the rolled and swollen part of the leaf varies; there may be spiral distortion also. Eggs are laid in cracks, scars and loose bark in winter, and on shoots and foliage in summer. Numerous nymphs inhabit one gall and moult 4 times within its shelter and a 5th on escaping from it. Eggs laid in October–November pass the cold weather and hatch in April at the time the new leaves appear. The 1st generation matures in June. The eggs of the 2nd generation laid in July take 2 months to hatch, producing nymphs in September, which mature in November. There are thus 2 generations a year each with a prolonged egg stage. Mathur, *tit. cit.*, pl. i, fig. 9.

P. malloticola galls the leaves of *Mallotus philippinensis*. [fig. 194, No. 5]. The galls occur on the upper surface of young leaves, are more or less globular, either separate or conglomerated into groups of several. A crowded mass of galls distorts or doubles up the leaf into a pouch-like shape. Each gall-chamber contains 1–4 nymphs. A female lays up to 230 eggs which hatch in 3 to 6 days. The nymphal stage last 60 to 110 days in hot weather and 150 to 180 days in cold weather. There are 3 generations a year with hibernation as a nymph that matures in March from eggs laid in October. Another species of **Phylloplecta** makes pit-galls on the under surface of leaves of *Mallotus philippinensis*. It has 5 generations a year.

Mathur R. N., 1935, *tit. cit.*, pp. 54-57, pl i, fig. 5, pl. ii, fig. 19.

Phylloplecta sp. [fig. 194, No. 6] makes pit-galls on the leaves of *Shorea robusta* in the form of numerous small shallow depressions on the under surface and slight swellings on the upper surface each containing one nymph closely pressed to the leaf. When a leaf withers the nymphs migrate to other young leaves. There are several generations during the growing season. Mathur, *tit. cit.*, pl. i, fig. 6. Another species of **Phylloplecta** makes large globular galls on the twigs of *Populus euphratica*, which vary in size from a pea to nearly ½ inch in diameter, and are formed on the youngest shoots and remain for several years. Two or exceptionally more galls may coalesce to form a common globular mass. They are frequently situated near the branching off of another shoot but may occur anywhere along the free length. The gall is a thick-walled cell containing one nymph; the inner surface of the wall is whitish green and spongy. When ripe the gall shrinks and splits by several fissures. The segments of the split gall reflex and with the growth of later years the base of the gall remains and expands into a rough scar. The period of initial attack by this gall insect is not known; the galls begin to orm in the winter and are fully developed in February. The adults emerge in March. The life-cycle is probably annual with a long resting period in the egg-stage.

Economic importance: The formation of the globular gall of poplar twigs diverts a certain amount of sap but not enough to kill the shoot locally or to reduce its growth seriously while the gall is tenanted. The drying up and splitting of the galls situated at or near bifurcations may cause distortion of growth by compelling the shoot to take off at an obtuse angle, or by killing back the leader in the direct line when the displaced lateral survives. This species is probably less important than the pit-gall of poplar twigs in causing dying-back of year-old shoots. The globular gall causes bifurcation and stepping of new growth but the vigorous thicker twigs appear to be very little affected by occasional galls.

Mathur R. N., 1935, *tit. cit.*, pp. 58-59, pl. ii, fig. 17.
Working Plan for Poplar Forests of the Muzaffargarh District, 1927, para 291 (b), 19.

Phylloplecta sp. forms pit-galls in the 1 and 2 year old twigs of *Populus euphratica*, which take the form of a deep, circular or oval pit with a swollen rim, each of which is occupied by one nymph. When the pits are crowded they form an irregular reticulation of the bark which completely checks the longitudinal growth of the twig although owing to the increase in bark-thickness, its diameter grows disproportionately. In severe attacks the twig dies in one season; when the insects are in more open formation there is considerable distortion and swelling of the bark which dies in patches. Internally there is a pink stain

extending into the cortex and a brown stain in the wood. The nymphs are unusually modified so that the dorsal surface is flattened and forms a roof to the pit, giving the appearance of a scale-like coccid or aleyrodid attached to the surface of the bark. The insect is not evident in the hot weather and the initial feeding appears to begin in winter. Adults emerge in March–April. The life cycle is annual with a long egg-stage. Mathur, *tit. cit.*, pl. ii, fig. 13.

Economic importance: Pit-galls are more abundant on *Populus euphratica* in the Indus forests than are the globular twig-galls due to the other *Phylloplecta*. The insect may check the growth of a twig entirely and kill it in one season, or reduce its growth in length, without killing it in the first season or cause dying-back of the subsequent years's shoot owing to the interference to its sap-supply due to the distorted tissues in the older part of the branch.

Psylla sp. lives on the leaves and green twigs of *Bauhinia variegata*. When the new foliage and flowers appear in spring they are infested with large numbers of nymphs of this insect. The flowers shrivel and fall and the leaves fold up and cease to develop. Growth is much reduced particularly in young plants. With the advent of heavy rain the psyllids are largely destroyed and the trees regain some vigour. A female may lay 1,500 eggs during an oviposition-period of 26 days; eggs hatch in 3 to 5 days in hot weather and in 7 to 10 days in winter. There are 5 nymphal moults and the nymphal stage lasts 10–30 days in hot weather and 25–60 days in cold weather. The adults are longer lived than most psyllids. There are 11 generations a year in north India. Mathur, *tit. cit.*, pl. ii, fig. 11.

Tenaphalara acutipennis lives free in the nymphal stages on the foliage of *Bombax malabaricum*, congregating on the underside along the midrib, but running actively when disturbed. The 5 nymphal instars are described by K. A. Rahman, 1932, *Ind. Journ. Agr. Sci.*, II, iv, pp. 367–370, pl. xxxvii (under the synonym of elongata.

Trioza fletcheri feeds on the leaves of *Gmelina arborea* and *Trewia* sp. and the form **minor** forms galls on the soft foliage of *Terminalia tomentosa*. The latter are small unilocular papillae on the upper surface of the leaf often very numerous (e.g., 500 per leaf). A gall opens by means of a slit which is clothed with a thick white pubescence. A leaf on which all the galls have opened appears riddled with punctures formed by the falling off of the dry cells. A female may lay over 500 eggs singly or in clusters scattered on young leaves and these hatch in 3 to 6 days. The nymphal period varies from 13–40 days in hot weather to 160-170 days in winter. Four moults occur in the gall and the 5th outside it. From March onwards in north India a series of 7 generations occurs varying in length from 16–45 days in hot

weather to 160-180 days in cold weather. The 8th generation from eggs laid in October overwinters in the nymphal stage inside the galls and emerges in March-April. Mathur, *tit. cit.*, pl. ii, fig. 10.

Trioza jambolanae forms unilocular galls on the leaves of *Eugenia jambolana*. The galls are on the upper surface either separate or coalesced into a group of two to eight. The mature gall loses its green colour, hardens and splits into several lobes. Mathur, *tit. cit.*, pl. i, fig. 8. **T. obsoleta** forms rough reddish-yellow galls on the leaves of young plants of *Diospyros melanoxylon*.

PYRRHOCORIDAE

Chatterjee N. C., 1938, *Ind. For. Rec.*, Ent., III, No. 11, pp. 214-217 (Pyrrochoridae of sandal (33).

Distant W. L., 1903-1910, *Fauna Brit. Ind.*, Rhynchota, II, pp. 94-121, figs. 73-87, — V, pp. 92-100, figs. 44-47.

Bugs of the genus **Dysdercus** are pests of cotton occurring in practically every cotton-growing country in the world.

Dysdercus cingulatus, The Red Cotton Bug.

The adult is bright red with the apical membranous area of the wing black and 2 black spots about the middle of the dorsum; length 10-16 mm. It feeds on various Malvaceae: *Abutilon indicum*, *Bombax malabaricum*, *Hibiscus cannabinus*, *H. esculentus*, *H. rosa-sinensis*, *Lantana*, *Solanum verbascifolium*, *Thespesia populnea*. Eggs are laid in a loose mass of 80-100 in in the soil. The nymph passes through 5 instars, becoming adult at the 5th moult but maturing sexually after some time. Nymphs and adults feed by sucking the sap from those parts of the plant that contain much sap or oil, e.g., cotton bolls, pods and fruits and seeds. Large numbers occur on semul trees during March-April when the flowers and pods are ripening and they descend to the ground to feed on the seeds when the pods open and fall. Reproduction is general and continuous until the food-supply ceases; periods of scarcity and hibernation are passed in the imaginal stages which are long-lived.

Lefroy H. M., 1908, *Mem. Dept. Agr. Ind.*, II, pp. 47-58, pl. v, The Red Cotton Bug.

REDUVIIDAE

ASSASSIN Bugs form a large family of useful predators which feed on caterpillars and small soft-bodied insects. Like some of the predaceous Pentatomidae, one Assassin Bug destroys a large number of injurious insects in the course of its life—an average of one a day for 6 months is not unusual for a large species. In the nymphal stage many species disguise themselves elaborately with particles of rubbish characteristic of their environment. Life-cycles vary from about one month in length to 2 generations a year. Sandal is frequented by 42 species.

Chatterjee N. C., 1936, *Ind. For. Rec.*, Ent., II, No. 11, Reduviidae of sandal (30).
Distant W. L., 1903-1910, *Fauna Brit. Ind.*, Rhynchota, II, pp. 196-403, figs. 139-257 — V, pp. 169-220, figs. 92-120.

Acanthaspis flavipes is a general predator on caterpillars. The nymph covers the whole body from the head to the tip of the abdomen and also the legs and antennae with various bits of rubbish, such as hairy or woolly filaments from leaves and bud- or seed capsules, fragments of bark, and dried twigs, straw, etc. piled up so as to conceal completely the form of the insect. One nymph of a brood may disguise itself in a manner completely different to that adopted by another nymph of the same brood. At the end of each instar the whole of this camouflage is discarded with the moulted skin and a fresh lot is acquired. In the nymphal and adult stages it feeds on caterpillars, eating one full-grown caterpillar of about the size of, e.g., *Ethmia systematica* (Yponomeutidae), *Hapalia machaeralis* (Pyralidae), *Plecoptera reflexa* (Noctuidae) or *Tephrina disputaria* (Geometridae) about every 2 days. The life-cycle is several months; the nymphs become mature in the hot weather June–September; eggs are laid in July, August. The adult bug lives for several months and through the cold season.

Acanthaspis quinquespinosa feeds on termites, caterpillars, coccinellid larvae and psyllid nymphs. The nymph disguises itself with particles of rubbish found in its haunts, sticking them all over its body. Eggs are laid in March-April (in north India) and remain unhatched through the hot season until the rains break in July. The oviposition-period of a female is about a month and 150–200 eggs are laid. The nymphal period lasts 8 or 9 weeks in July-September when they become adult or else hibernate from October to February, March in the 4th and 5th instars. There are thus 1 to 2 generations a year.

Ullah G., 1940, *Ind. Journ. Ent.*, II, p. 94.
Rahman K. A., 1940, *Proc. Ind. Acad. Sci.*, XII, p. 73.
Pruthi H. S., 1941, *Proc. 28th Ind. Sci. Congr.*, Abstracts, p. 200.

Acanthaspis sp. feeds on the caterpillars of teak defoliators and other species. Eggs are laid in a cluster of about one dozen on twigs; in July the egg hatches in a week or two. The nymph undergoes 5 moults within a period of 7 weeks. Adults formed at the end of August live on for the remainder of the year. A nymph eats about 30 caterpillars during its life or approximately 2 every 3 days. The adult bug requires one caterpillar every 2nd or 3rd day during its active season.

Species of **Coranus** and **Ectomocoris** are predaceous in the nymphal and adult instars on caterpillars of *Plecoptera reflexa* (Noctuidae) and *Margaronia pyloalis* (Pyralidae). Individuals live for several months during the hot weather June–September.

Lisarda annulosa feeds on *Margaronia pyloalis.*

Rhinocoris fuscipes is predaceous on caterpillars of *Tephrina*

disputaria (Geometridae), *Anaphaeis messentina*, *Laphygma exigua*, *Noorda biliteails*, *Plecoptera reflexa*, *Prodenia litura*, *Spodoptera mauritia* and other Noctuidae; and on Aphidae, coleopterous larvae, etc. The eggs are oblong, 5 mm., laid in batches of 5 to 40; they hatch in 5 to 7 days. The 1st instar nymphs are orange with a black tip to the abdomen which is usually cocked up, giving them an ant-like appearance. After the 6th nymphal instar the bug becomes adult. The life-cycle is completed in 30 to 50 days in south India. Eggs are laid in June, July in north India. There is a pre-oviposition period of 2 or 3 days and egg-laying follows at the rate of 5 to 40 eggs in a day up to a total of about 340. The adult lives for several months and may kill and suck 5 caterpillars a day. Two or three bugs may combine to attack a full grown noctuid caterpillar.

Cherian M. C. and Kylasam M. S., 1939, *Journ. Bomb. Nat. Hist. Soc.*, XLI, pp. 256-259.

Sirthenea flavipes feeds on nymphs of *Urostylis punctigera*.
Sphedanolestes dives kills caterpillars of *Hapalia machaeralis*.

Sycanus collaris

This bug feeds on various caterpillars including teak defoliators (*Hapalia machaeralis* and *Hyblaea puera*), shisham defoliator (*Plecoptera reflexa*), *Margaronia laticostalis*, *Nephopteryx rhodobasalis*, etc. It does not normally touch pupae or butterfly caterpillars.

L i f e - h i s t o r y : A female may lay 100–300 eggs in batches of 40 to 100 at a time over a period of 7 weeks. The egg is about 2 mm. by 0·6 mm., yellowish-brown, deposited upright and closely cemented to the other eggs in the batch which is surrounded with hardened froth. The top of the egg bears a thin reticulated collar and is pushed off as a circular cap when the nymph emerges. Immediately after escape from the egg the nymph sheds an embryonic skin. During the nymphal period there are 5 additional moults. There are 2 generations a year, the first starting from eggs laid in June to August and the second from eggs laid in October–November. The egg of the 1st generation hatches in 2 weeks and the 5 nymphal stages are completed in a period of about 50 days. The adult bugs appearing from September onwards live several months, eventually dying in the spring after hibernating. Pairing and oviposition take place at intervals during active adult life after a prematuration-period of 2–3 weeks. Eggs of the 2nd generation laid in November take 35 days to hatch. Eggs laid later pass the cold weather without hatching. The 1st stage of the free nymph occurring in the cold months may require 85 days for its instar, moulting in March. The 2nd to 4th instars are completed in 10 to 20 days each giving a total period of about 145 days as a nymph in this generation. The nymph eats caterpillars at the rate of about one every other day and the adult may take one caterpillar a day while active. Paralysis of

the prey takes place immediately after the proboscis is inserted and the colour of the caterpillar deepens to black. This predaceous bug often swarms in large numbers on trunks of trees in the autumn and appears able to increase rapidly during epidemics of defoliators. It is stated to keep *Nezara viridula* (Pentatomidae) under control in the Malay Peninsula.

Chatterjee N. C., 1936, *tit. cit.*, pp. 214, 215 (literature).

Sycanus falleni attacks caterpillars of *Hapalia machaeralis*.

TINGITIDAE

LACE BUGS have the hemelytra reticulate with the numerous cells bounded by thickened lines and producing patterns resembling coarse lace and fine gauze. Most species are small, 2–5 mm., and inconspicuously coloured in dark grey, brown or black. The minute eggs are partially inserted in the venous tissue of leaves; nymphs feed gregariously on the under surface of new leaves sucking the sap and possibly injecting a toxic saliva which hastens the death of the foliage. Life-cycles are completed in 4–6 weeks in the season of most rapid development.

LITERATURE ON TINGITIDAE:

Chatterjee N. C., 1938, *Ind. For. Rec.*, Ent., III, No. 11, pp. 217-218, Tingitidae of sandal (33).

Distant W. L., 1903-1910, *Fauna Brit. Ind.*, Rhynchota, II, pp. 122-145, figs. 88-107 — V, pp. 100-126, figs. 48-66, Tingitidae.

Drake C. J., 1929, *Ind. For. Rec.*, XIII, vi, p. 283. A new subgenus and species of Tingis from Burma.

Drake C J. and Poor M. E., 1936, *Ind. For. Rec.*, Ent., II, No. 5, pp. 141-149, fig. 1, New Indian Tingitidae.

Cysteochila delineata occurs on *Bauhinia purpurea*. **Physatocheila dryadis** on leaves of *Quercus dilatata*. **Stephanitis gallarum** on *Machilus gamblei*. **S. typicus** on the racemes and fruits of *Elettaria cardamomum*.

Teleonemia scrupulosa, The Lantana Bug

Previously known as *Teleonemia lantanae*, this lace bug is one of the lantana insects that were introduced by Koebele in 1902 from Mexico to Hawaii (see Biological Control of lantana, Part Two). In 1928 it was transferred from Hawaii to Fiji and in 1935 thence to Australia. In 1941 a colony of 80 adults was imported by air mail from Canberra, Australia, to Dehra Dun by the Forest Entomologist. The stock has been multiplied to provide material for exhaustive tests of the bug's ability to damage economic plants and particularly verbenaceous trees, which are essential before it is known that liberations on *Lantana aculeata* can be safely made in India.

Life-cycle: *T. scrupulosa* is about 3·5 mm. long when full-grown, with a long punctured and ridged pronotum, extending beyond the bases of the reticulate wings. The nymphs have spines over and at the sides of the abdomen. Eggs are laid in lots of 10–30 partly inserted in the midrib or main veins of the under

surface of young leaves at the ends of growing shoots. The cellular tissue of the leaf immediately around the egg dies and the leaf becomes much distorted. Hatching takes place in 7 or 8 days. The young nymph sucks the sap from the green tissue on the under surface of the leaf-blade. There are 5 nymphal instars which are gregarious and sluggish except the last which tends to disperse to more distant leaves on the same shoots. They become adult in about 12–18 days making a life-cycle of about 20–25 days. Adults are long-lived, up to 3 months, and are active fliers; they prefer to feed on lantana flowers puncturing the tubular part. Pairing occurs a few days after moulting and oviposition begins a week later.

Feeding-habits: Entire cell-contents are sucked up so that the mid-gut of an individual that has fed on leaves is coloured green (due to chlorophyll) and that of one feeding on flowers is coloured orange (due to chromoplasts). The lantana leaf discolours and blackens from the apex and sides, curling up and dropping off when dry, leaving the leafless shoots which die back from the tips. Flower-buds and flowers are attacked before the inflorescence has opened as well as when in full bloom; the whole flower-head is killed before seeds are formed.

In Australia it has been noted that the feeding of the lantana bug systematically affects the growth of the plant as a whole. Young terminal growth, and young stems which show no signs of having been attacked themselves, become distorted, turn yellow and cease to grow. These stems if not subjected to further attack can produce new growth. Adventitious shoots appear round the crown and later fresh shoots arise from the stems; these new growths are particularly attractive to the bugs. It is probable that the lantana bug injects into the feeding-punctures saliva which has a toxic action on the tissues of the lantana plants (Fyfe). The action is in some ways similar to that of the pentatomid *Urostylis punctigera* on *Michelia champaca*.

Biological control of lantana: In the Hawaiian Islands the destructive capabilities of the bug are not unimpressive but cannot be entirely separated from the effects of other introduced lantana insects. In Fiji it did not show itself remarkably promising owing to its susceptibility to local predators and disease. In Australia the earlier liberations did not give particularly encouraging indications but in 1939 it became evident that it is capable of destroying lantana flowers and shoots to a very useful extent under favourable conditions and has even done spectacular damage to lantana in one area in tropical Queensland following a single liberation. It is probable that in one or more of the climatic regions of India *T. scrupulosa* will flourish and may cause wholesale destruction of lantana where the scrub is dense and extensive enough to keep up an accessible sequence of flowers and new shoots during the first epidemic period after colonisation. One

may expect phases of great damage to lantana to alternate with phases of recovery and regrowth until competitive vegetation has become dominant. Even if *T. scrupulosa* meets with serious opposition in India from disease and predators it is still a species that could be used to assist forestry operations designed to replace lantana by tree crops. But before an initial liberation is made it must be authorised by a coordinated policy which agrees that the extermination of lantana is in the general interests of agriculture, forestry and rural development.

Beeson and Chatterjee N. C., 1940, *Ind. For. Rec.*, Ent., VI, No. 3, Possibilities of control of lantana by indigenous insect pests.

Tingis beesoni, 4 mm. × 1·7 mm., a dark or black species with the reticulation hairy, breeds on *Gmelina arborea* in India and Burma assembling in crowds on the leaves and soft shoots. Nymphs and adults feed almost entirely at the base of the leaf-blade on the under surface or at the axils. The leaf becomes spotted or patched with brown near the base; the discolouration may spread for 2 inches on both sides of the lamina. Attacked leaves wither and fall and a young plant may be completely defoliated; the shoots dry up and turn black; a sooty mould grows overall. It is possible but not proved that a bronze disease of *Gmelina arborea* is associated with the lace bug. Plantations are attacked in the 1st or 2nd year and are susceptible up to the pole stage.

Between mid-May and October in Dehra Dun there are 3 generations each lasting about 6 weeks. In the autumn adults continue to frequent the plants. It is not known in what stage hibernation occurs. As completely defoliated *Gmelina arborea* tends to remain leafless for several months, if not until the following year, it is unlikely that this interval is bridged in the egg or nymph stage.

Trachypeplus jacobsoni, a widespread species, feeds on *Mallotus philippinensis*.

SIPHONAPTERA

THIS very small Order consists of the highly evolved Fleas which are not closely related to any other group. The adults are specialised blood-suckers on warm-blooded vertebrates; eggs are laid in dust on the ground and produce active legless larvae which feed on the excrement of adult fleas and dead organic matter found in the dust of the living-quarters of their hosts; the 3rd instar larva pupates in a cocoon. The life-cycle takes about 4–6 weeks. Adult fleas live several weeks without food; it is not uncommon to find numerous unfed voracious fleas in houses that have been unoccupied for long periods.

LITERATURE ON SIPHONAPTERA:

A volume in the *Fauna of British India* (Aphaniptera) by M. Sharif is in preparation.

Patton W. S. and Evans A. W., 1929, *Insects, ticks, mites and venomous animals of medical and veterinary importance, Part 1.*
Sharif M., 1930, *Rec. Ind. Mus*, XXXII, p. 29, A revision of the Indian Siphonaptera, Part I, Pulicidae.
Sinton J. A., 1925, *Ind. Journ. Med. Res*, XII, pp. 471-478, The Indian rat-fleas with special reference to the identification of plague fleas.

Ctenocephalus canis is a common dog flea and has spread with its host all over the world, flourishing best in colder regions; in India it occurs on cats, jackals and attacks man. **C. felis** is cosmopolitan in all climates but flourishes best in tropical countries. Its chief hosts are cats and dogs and it occurs on many wild carnivores and readily attacks man. The subspecies **orientis** is common throughout India on dogs, goats, cattle and occasionally on cats, sheep and rodents.

Echidnophaga gallinacea, The sticktight flea, is an almost cosmopolitan flea infesting poultry but occasionally attacking other domestic animals.

Pulex irritans, the common flea of Europe, is practically cosmopolitan; in India it is found mostly in hilly regions and rarely in the plains. In addition to man it attacks domestic animals (dog).

Xenopsylla cheopis, the vector of bubonic plague bacillus, is now the common rat flea in India whither it was introduced from Africa before about 1890 when plague was first recorded in India, and to Ceylon before 1914 when plague first appeared on that island. It is less abundant in the warmer and moister regions and is predominant rat-flea in the northern mountains.

Cragg W. F., 1923, *Ind. Journ. Med, Res.*, X, p. 953, Further records of the distribution of Indian rat fleas, and correlation between the prevalence of Xenopsylla cheopis and plague mortality.

THYSANOPTERA

THE ORDER THYSANOPTERA.

THRIPS are very small, practically microscopic insects, 0·5-3 mm. in length (a few species reaching 9 mm.), yellowish, brown, bright red or black in colour, living in buds and flowers, on leaves and in leaf-galls and under decaying bark and in rotten wood and fungi. Most species of THYSANOPTERA feed on plant-sap which they obtain by gashing or scratching the surface-tissues. The mouth-parts are of unique structure, intermediate between the chewing and the piercing-sucking types. On the underside of the head-capsule is a short conical projection composed of the clypeus and labrum above and the labium below, which terminates in a small mouth-aperture around which are the maxillary and labial palps. Inside the cone are the 3 stylets, or piercing organs, formed by the left mandible and parts of the two maxillae; the right mandible is vestigial in the Terebrantia and more developed in the Tubulifera. When a thrips feeds the tip of the mouth-cone is applied to the surface of a leaf and the head rocked to and fro

with the mandibular stylet protruded. With each stroke the wall of the epidermal cell is gashed by the stylet until it is broken down and a hole formed from which the cell-contents can be sucked out. Where the epidermis is injured it dies and turns brown.

The wings of the adult thrips (macropterous forms) are characteristic; the slender very narrow wing-membranes would not be sufficient to sustain the insect in flight without the extra width and surface formed by the close-set fringes of long hairs. Fig. 194 shows a winged male. In some species one sex and in other species both sexes are wingless (brachypterous forms). The tarsi have no claws but terminate in a remarkable protrusible bladder which is retracted when the thrips is at rest and protruded when it is walking. In the Terebrantia the females have an ovipositor; in the Tubulifera there is no ovipositor but the last abdominal segment in both sexes is tubular. The eggs are elongate-oval or kidney-shaped and are laid singly or in groups on the surface of plants, in slits in the epidermis of leaves, in flowers and buds, under bark, etc. There are 4 or more nymphal instars resembling the adults in appearance and in habits; the 3rd and 4th do not feed but remain inactive (though capable of movement: prepupal and pupal stages). A series of generations during the course of the year is probably usual with subtropical species; in south India the life-cycle from egg to adult lasts 4 or 5 weeks. Northern species may have one generation.

E c o n o m i c i m p o r t a n c e: Although thrips occur very commonly in flowers, buds and in other sheltered positions on forest trees and damage the young tissues, the extent to which it is important has not been decided. About 250 species have been recorded from India, and named by Ramakrishna Ayyar, Karny, Moulton, and Priesner. The drainage of the plant-sap by Thripidae causes flowers to fade and drop prematurely, and buds to shrivel up. Phloeothripidae feed abundantly on leaves and cause them to become distorted and to curl up; some species form definite leaf-galls or woody stems-galls which are frequently inhabited by other species as well (*Liothrips, Mesothrips*). Thrips also occur in galls made by other insects (*Androthrips, Rhynchothrips*). Whilst most Thysanoptera are sap-suckers, some species of Phloeothripidae are predaceous on small bark-inhabiting insects and mites or their eggs. *Ecacanthothrips sanguineus, Dichaetothrips beesoni* and *Dinothrips gardneri* occur under bark attacked by Scolytidae.

LITERATURE ON THYSANOPTERA:

Ayyar T. V. R., 1925, *Journ. Bomb. Nat. Hist. Soc.*, xxx, pp. 861-871, Annotated list of the Thysanoptera known from India and Ceylon.

— 1928, *Mem. Dept Agr. Ind.*, Ent, x, 7, pp. 217-316, A contribution to our knowledge of the Thysanoptera of India.

— 1932, *Agr. Livestock Ind.*, II, pp. 391-403, pls. xvi, xix, Bionomics of some thrips injurious to cultivated plants in south India.

— 1934, *Ind. For. Rec.*, xx, IV, Entomological investigations on the spike disease of sandal (21), Thysanoptera.

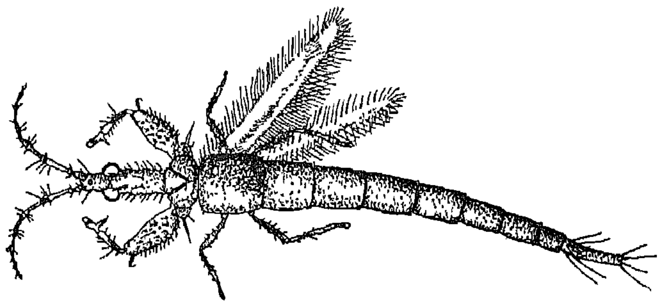


Fig. 194, Elaphrothrips beesoni, male, 9 mm.

Ayyar T. V. R. and Margabandhu V., 1940, *Catalogue Ind. Ins.*, Part 25, Thysanoptera, 64 pp.
Moulton D., 1929, *Ind. For. Rec.*, XIII, vi, pp. 285-292. — 1929, *Rec. Ind. Mus.*, XXVI, pp. 93-100. — 1923, *Ind. For. Rec.*, XIX, i, 6 pp., New Thysanoptera from India.
Priesner H. Von, 1933, *Rec. Ind. Mus.*, XXXV, pp. 347-369, Indomalayische Thysanopteren, v.

PHLOEOTHRIPIDAE

Androthrips flavipes in leaf-galls of *Ficus retusa* and *Mimusops elengi* and in psyllid galls on leaves of *Terminalia*. **A. ramachandrai** in galls of *Calycopteris floribunda*.

Arrhenothrips dhumrapaksha in leaf-galls of *Ficus retusa*. **A. ramkrishnae** in leaf-galls of *Mimusops elengi*, in south India throughout the year and causing considerable injury to the tender foliage which is wrinkled or deformed. The two halves of the leaf meet together and form a tube-like chamber containing all stages of the thrips.

Austrothrips cochinchinensis in large cankered woody galls on the leaves of *Calycopteris floribunda* and *Cordia myxa* in company with *Androthrips ramchandrai*; some galls may be 2 inches in diameter.

Brachythrips dirghavadana in leaf-galls of *Ficus retusa*.

Dichaetothrips beesoni under bark of *Ficus religiosa* attacked by Scolytidae.

Dinothrips gardneri under bark of *Shorea robusta* attacked by *Sphaerotrypes siwalikensis*. **D. sumatrensis** under bark of numerous species of trees.

Dolicothrips indica on shoots of *Santalum album* and flowers of *Melia azedarach*.

Elaphrothrips beesoni, 9 mm., [fig. 194] and **E. chandana**, 6 mm., are giant thrips found on the foliage of *Santalum album* in south India.

Eothrips foliiperda in leaf-galls of *Pothos scandens*; the leaf is rolled longitudinally, turns yellow and becomes brittle. **E. jambuvasi** in leaf-galls of *Eugenia jambolana*.

Gynaikothrips caseariae on leaves of *Casearia graveolens*.

G. malabarica rolling the edges of young leaves of *Ficus indica.*

Liothrips bosei, L. brevitubus and **L. flavitibia** in the leaf-galls of *Mallotus philippensis* together with *Mesothrips malloti.*

L. gardneri on leaves of *Casearia tomentosa.*

Mallothrips indica in leaf-galls of *Eugenia jambolana.*

Mesothrips apatelus and **M. bhimabahu** in leaf-galls of *Ficus retusa.* **M. malloti** in leaf-galls of *Mallotus philippinensis.* **M. melinocnemis** in leaf-galls of *Pothos scandens.*

Neoheegeria indica in shoots of *Ailanthus excelsa, Cochlospermum gossypium* and *Melia azedarach.*

Rhynchothrips champakae curls the leaves of *Michelia champaca.* **R. palasae** in stem-galls on *Butea frondosa* formed by *Pachyonyx quadridens* (Curculionidae). **R. raoensis** in leaf-galls of *Mallotus philippinensis*; each half of the leaf is rolled towards the midrib and the whole leaf becomes a tube of which the surface is grooved and wrinkled.

Thilakothrips babuli in leaf-galls of *Acacia leucophloea.* The gall sheltering all stages of the thrips occurs in September-October in the form of a rosette of dark brown leaflets on the midrib of the distal leaves of a shoot.

THRIPIDAE

Limothrips cerealeum, a cosmopolitan pest of cereals, occurs in leaf-galls of *Mimusops elengi* in India.

Mycterothrips setiprivus in shoots of *Acacia suma.*

Perissothrips parviceps in shoots of *Acacia suma* and *Ailanthus excelsa* and flowers of *Caesalpinia pulcherrima.*

Pseudodendrothrips ornatissimus in shoots of *Acrocarpus integrifolia,* and *Morus indica.*

Rhipiphorothrips cruentatus, the Grape-vine Thrips, widely distributed in India, feeds on numerous woody plants including *Anacardium occidentale, Careya arborea, Eugenia jambolana, Lannea grandis, Terminalia arjuna, T. catappa, Vitis vinifera.* Eggs are laid in slits sawn with the ovipositor in a leaf, up to 50 eggs by one female. They hatch in 4–6 days. There are 4 nymphal instars, the 3rd being the prepupa and the 4th is termed the pupa; these stages develop in 11–25 days except in winter when the pupal stage hibernates in the soil from mid-November to March. The total life-cycle varies from 14 days to 33 days but there are only 5 to 8 generations a year (according to climate). The life-history, economic importance and control on grape vines are given by Rahman K. A. and Bhardwaj N. K., 1937, *Ind. Journ. Agr. Sci.*, VII, pp. 633–651, pls. lii-lv (with previous literature).

Taeniothrips cardamomi attacks the buds and blossoms of *Elettaria cardamomum* causing shedding of the buds and scabbing or malformation of the capsules. Peak infestation is reached in May when the blossoms are most abundant. In bad infestations

preventing the setting of most of the flowers there is a very serious loss of crop; when the injury is less extreme and fruits are formed, the feeding-punctures of the thrips produce rough corky scabs varying from small spots on the angles to extensive scabbed areas which reduce the weight and spoil the appearance of the cardamom capsules, seriously affecting their market value. The pest first appeared in 1934 in the Anamallai Hills and was reported subsequently in other localities in Travancore, Madras and Mysore. The sudden appearance of thrips and its rapid spread over the whole cardamom-producing area combined with a series of climatically unfavourable years had by 1940 brought about an enormous reduction in yield and threatened many plantations with extinction. The investigation of pests and diseases of cardamom cultivation is now undertaken by the United Planter's Association of South India and the Governments of Travancore and Madras financially assisted by the Government of India.

T. niloticus in shoots of *Acacia arabica* in south India.

Scolothrips sexmaculatus is predaceous on leaf-mites (Acarina).

THYSANURA

THIS small order of apterygotous insects forms part of the insect fauna of damp earth, humus, moss, etc., of rotting bark and other vegetable matter; some species of fish insects live in buildings, e. g.,

Lepisma. The fish insect found in houses is about 15 mm. when full grown, silver-grey in colour due to a covering of scales. The female lays 6-10 eggs at a time in crevices, accumulations of rubbish, cupboards, and in folded clothing, etc. The eggs take 40-60 days to hatch at room-temperatures of 18°-20° C. but in tropical heat they hatch in 6-10 days. The newly emerged nymph resembles the adult in general form, but is without scales which develop gradually. The fish insect grows relatively slowly and does not attain maturity for about 2 years in colder climates and in 7-9 months in tropical climates. They are gregarious and live preferably in dark places; if suddenly exposed to light they attempt escape by short but rapid runs. Feeding occurs mainly at night on whitewash, paper, books, and book-bindings, photographs, pictures, and on delicate fabrics such as tulle, silk, muslin, starched linen and lace, sized silks and rayons, etc. in which holes are eaten. Starch appears to form the chief constitutent of the diet; proteids are possibly obtained by feeding on Pscoptera and mites (Acari) living in the same environment. They are able to live for several months without food. In wet and cold weather they are sluggish and do not feed or breed freely; at high temperatures the length of life is reduced. For control measures see Part Two.

PART TWO

THE CONTROL OF FOREST INSECTS

A new difficulty came into Alice's head.
"Supposing it couldn't find any food?" she suggested.
"Then it would die, of course."
"But that must happen very often," Alice remarked thoughtfully.
"It always happens," said the Gnat.

(Through the Looking Glass.)

THE ABUNDANCE OF INSECTS.

AN OUTSTANDING FEATURE of wild animal populations is that they fluctuate greatly in numbers. For any given species of animal the population-density (i.e., the number of individuals on a given area at a given time) differs in different places, and these differences in density are related to differences in climate and in other factors of the environment. Moreover, in any particular place the population-density of a species fluctuates about its average, varying in close association with the changing seasons. These fluctuations are not those which result from developments of human civilisation in which man has interfered with natural conditions. They are due to the fact that the densities of animal populations always tend to be in a state of balance with their environments and consequently they vary with normal environmental changes. These changes may be brought about (a), by external disturbances in the environment, and (b), by internal oscillations peculiar to an animal-community. One way of comprehending the numerical abundance of forest insects and the potential economic status of a particular species in a particular area is to imagine it as dependent on the interaction of two opposing forces, one of which is the ability of a species to reproduce its own kind, to survive and multiply, and the other is the destruction of individuals of a species by the various factors of its environment. The inherent power of an organism to survive, reproduce and multiply in the face of the destructive factors of its environment is termed the **biotic potential.** A species which is able to multiply considerably in spite of adverse factors in its environment is said to have a high biotic potential; while one that practically makes no headway against the resistance of its environment has a low potential. The destructive forces of the environment are termed **control** of which there are several factors (see page 797).

The Reproductive Potential.

The constructive force in the biotic potential of an insect is its reproductive potential, which is the potential number of descendants of one pair of insects in a given period, assuming there is no environmental resistance and therefore no mortality among the descendants before each completes its full possibility of reproduction. Its value depends on fecundity, sex-ratio and the length of the life-cycle.

Fecundity: Among insects there is a wide range of variation in fecundity, but in general, compared with that of more familiar animals, it is relatively high. The number of eggs laid by, or young born of, a single female may range from less than ten to hundreds of thousands.

E.g., (a) the brood of a solitary shothole borer such as *Xyleborus discolor*

(p. 395) or of a lethargic parasite such as *Cedria paradoxa* (p. 476) may be less than ten. (b) The number of eggs laid by many moths is between 100 and 600. (c) The queen of a honey-bee, *Apis mellifica*, lays 2,000 to 3,000 eggs a day. (d) The most fecund female insect is the queen termite who lays millions of eggs in her life-time at the rate of one every 2 or 3 seconds.

Sex-ratio: The sex-ratio affects the biotic potential according to proportion of females in a species. The potential is highest in parthenogenetic reproduction giving rise to females only; it is less in species with the sexes occurring in equal numbers and it is least in species with an excess of males.

Life-cycle: A short life-cycle, obviously confers a higher reproductive potential than a long life-cycle, for the same period of time; the normal length of the life-cycle is one of the most important items of information that can be obtained about an insect pest.

In order to illustrate the potential rapidity of increase of insects due to a high fecundity and a short life-cycle various entomologists have calculated the numbers that would be reached by the progeny of an original pair in the course of a year or so of unchecked increase:

E.g., the progeny of a pair of pink eyed fruit-flies, *Drosophila*, would in course of a year amount to a mass that, if packed at the rate of a thousand to the cubic inch, would cover the entire area of India from Kashmir to Cape Comorin, from Karachi to Calcutta, in a solid layer to a depth of 100,000,000 miles; or the whole earth to a depth of one million miles. "And yet as it is we do not particularly notice them." (Lefroy).

Incredible as the results of a high reproductive potential may appear the fact must not be overlooked that enormous populations could arise from quite low reproductive potentials given the necessary length of time. Taking a slow breeder like the elephant, for example, it would not require a historical period to populate India entirely with elephants so closely packed that they would be unable to sit down.

Such calculations are not wholly fantastic: they demonstrate vividly the controlling effect of the destructive factors of the environment,—an operation that is not ordinarily realised until they fail, and plagues of mice or locusts or rats or flies appear. These storms of breeding and death are normal occurrences and have been recorded from the dawn of history.

Control

The destructive force affecting the biotic potential of an insect is the resultant of the combined action of all the control factors of its environment, and is sometimes termed the environmental resistance.

In it there are two distinct processes (a) control factors which act irrespective of the density of the population,—i.e., the effects of climate, food-supply and external catastrophes; and (b), those which depend on the density of the population—i.e., competition, natural enemy action. The first acts in a random manner whether the species of insect is abundant or scarce, and destroys the same proportion in either case. The second is connected with the

actual density of the species and acts as a form of automatic control.

The term 'control' may be defined as a check in the increase of the population of an insect brought about by a single factor or a combination of any kind. *If there were such a condition as a constant environment control would destroy the surplus of the population and maintain it unchanged from generation to generation in a stationary state of balance with that environment. This steady state is usually of short duration in nature but, nevertheless, it is an important theoretical consideration.

Control can be classed as **natural control**, i.e., the reduction in the reproductive rate of a species caused by the natural factors of the environment; or as **artificial control**, i.e., the reduction in the reproductive rate of a species caused by the intervention of man.

A CLASSIFICATION OF CONTROL.

NATURAL CONTROL:

1. Climatic Control.	Meteorological factors, temperature, rainfall, atmospheric humidity, wind, sunshine, light, moon; topographic features, mountains, plains, zoogeographical distribution.
2. Nutritional Control.	Food-supply quality, alternative food-plants, host-resistance, food-supply quantity, pure stands, competition.
3. Biotic Control.	Disease-producing organisms, fungi, bacteria, protozoa; insect parasites and predators, vertebrate predators, birds, lizards.

ARTIFICIAL CONTROL:

4. Silvicultural Control.	Virgin, natural and artificial forest; choice of silvicultural system, regeneration areas, clear-fellings, pure crops, monocultures, mixed crops; polyphagous pests, monophagous pests, composition of artificial mixtures, thinnings.
5. Biological Control.	Utilisation of parasites, specific and polyphagous parasites; utilisation of predators; utilisation of diseases; introduction and colonisation of new species.
6. Mechanical Control.	Barriers, screens, fly-nets, tree-bands, deterrents, traps, bagnets, probes, debarking, pruning, submersion in water, sunheating, charring.
7. Chemical Control.	Insecticides, stomach-poisons, dusts, sprays and dips; contact-poisons, dusts, sprays and dips; fumigants; repellents, attractants, impregnation and preservative treatments.

THE FACTORS OF NATURAL CONTROL

The chief aim of economic entomologists is not to devise control measures that are merely applicable to existing conditions, but to foresee and prevent outbreaks of insect pests. "In order that they may be able to do this, all conditions accompanying and

*Some authors would limit *control* to checks which depend on the density of populations. It has also been postulated that "controls" are topographic or climatic, and are not "factors" but only influence the values of factors, which are physical or biotic. By others the word is used loosely as though synonymous with "control measures" or "economic control".

causing outbreaks must be thoroughly investigated and elucidated; in other words, the epidemiology of insect pests must be the central problem of economic entomological research, which should be carried out from the ecological point of view. The ecological conception of economic entomology consists in the recognition of the injurious insect as an integral part, and even as a product of its environment". (Uvarov). "The tropical entomologist or mycologist or weed-controller will only be fulfilling his functions properly if he is first and foremost an ecologist" (J. Huxley). The forest officer should think of pest control in terms of animal ecology and not of the flit-gun.

1. CLIMATIC CONTROL

THE relative importance of the natural factors controlling the abundance of an insect species is one of the main problems of ecology. Opinions differ and continue to change as to whether annual populations are controlled chiefly by climatic or by nutritional or by biotic factors; but there is much circumstantial evidence and some limited but weighty experimental deductions to show that climate really controls population-density. Under normal conditions climate is the main destructive force in natural control; *by normal conditions is meant that the population-density* has not approached the point at which the capacity of the environment is saturated (Bodenheimer).

Climate is the combination of all the meteorological factors occurring throughout the year in a particular locality; the term as ordinarily used implies the average of normal conditions experienced over a long period of time.

Weather *is the combination of all the meteorological factors of a* particular locality occurring at a particular point of time, and it varies from *hour to hour, and season to season.*

Climate determines the composition of the flora and fauna of an area. It influences the relative abundance of an insect-species within the area and it determines the length of its life-cycle and of the successive stages in the life-cycle, and the number of cycles possible in a year. Weather conditions affect the abundance of an insect species in a particular stage at a particular time or place. Any studies on a living insect must begin with the investigation of its climatic environment. The chief climatic factors are **temperature, rainfall** and **snowfall, atmospheric humidity** and **pressure, sunshine** or **light, wind.**

The primary effect of each factor on the insect-world may be considered separately but it must be remembered that in nature they rarely work independently. The action of atmospheric temperature is always modified by the relative atmospheric humidity at the moment, and changes in these two factors often occur in opposite directions. As air-temperature rises its humidity usually decreases and as the temperature falls its humidity increases. Very high air-temperatures may be accompanied by extreme dryness or by saturation, but air at the low temperature to which

insects are ordinarily exposed is moist. Rainfall is usually accompanied by a reduction of temperature and a rise in atmospheric humidity. Sunshine and wind may have a drying effect on the insect or its immediate environment. Wind alone may cause a fall in local temperature by evaporation and radiation The evaporative power of air, which is a combination of the various meteorological factors, is probably the best index of the effect of climate on an insect species.

The climate to which an insect species is exposed is, however, that of its habitat, which may differ from that of the locality. The sum-total of the meteorological factors within a habitat is termed the **eco-climate**. Thus the eco-climate of a borer inside a log is small and comparatively homogeneous. That of a bird is of greater spatial extension and more complicated.

Temperature.

Temperature is the most important single physical factor in the environment. There is for each species of insect a definite range of temperature between the extremes of which the insect is active and metabolism or growth is apparent. Within this range of *effective temperature* there is a point, or narrow zone at which the temperature is most favourable and activity is greatest, known as the *optimum temperature* for that species; increase or decrease of temperature from this point retards metabolism. On passing *the critical points or thresholds of development at the maximum* or the minimum limit of the range of effective temperature, its metabolism is so much retarded that the insect becomes completely inactive or dormant. At still higher or still lower temperatures the dormant insect is liable to die, the liability depending on the actual temperature and the length of exposure to that temperature. Finally, a point is reached at and above which death is instantaneous and there is a correspondingly low point, below which life is impossible. The influence of the external temperature on the activity of the insect is not direct but acts through its body-temperature, which differs from that of the surrounding air and can to some extent be regulated by the insect.

Low temperatures: Insects are very resistant to low temperatures. The fatal minimum is probably somewhere about $-10^{\circ}C$ for the most resistant species. Temperate species are more resistant to cold than tropical species and the latter succumb more readily to unusually cold weather. The faculty of remaining dormant at low temperatures below the minimum effective temperature is exercised in nature during the winter-season, and in consequence is termed *hibernation* (or winter sleep). In experimental biology use is made of this faculty by cold storage of insects in refrigerators, e.g., when breeding and storing parasites, or in sericulture, in order to maintain a supply of eggs. In those parts of India with a true winter-season, hibernation is the normal

method of passing the cold weather and may take place as an egg, a larva or nymph, pupa or imago according to the species. During this period of quiescence, respiration, excretion and other metabolic processes cease or persist only at a low level, and such energy as may be needed is supplied by the reserve food in the fat-body. In south India and the moist regions where frosts are absent true hibernation does not occur. Species of wide distribution ranging from the tropical to subtemperate regions adjust themselves to the local climate.

Thus the two teak defoliators, *Hyblaea puera* (p. 609) and *Hapalia machaeralis* (p. 676) hibernate during the period November-March at Dehra Dun, U. P., but are continuously active during this time at Nilambur, in Malabar. Some insects like *Calopepla leayana* (p. 222), which hibernates as a beetle and continues inactive through the spring and dry hot weather, combine hibernation with aestivation. Here the process is more complex and is probably modified by a rhythm induced by absence of food.

Insects vary much in their resistance to frost or freezing. Among species that are capable of enduring low temperatures for a long period of dormancy we find that some species are killed when a sudden drop of temperature causes their tissue to freeze; while others can survive freezing and recover when thawed out by subsequent warmer weather, but if frozen again by a late frost they are killed; hence frosts in late spring or after a spell of mild weather often cause great mortality among species that have survived more severe frosts earlier in the season.

Effective temperatures: The minimum effective temperature or threshold of development for insects generally is between 5° and 15° C. but it is not the same for different insect species and varies under the influence of other climatic factors. Some insects are active at temperatures slightly above the freezing point of water, and many species are not active until about 20° C. The movements of locust hoppers cease when the temperature drops below 13°-15°C. The lac insect, *Laccifer lacca*, (p. 752), does not begin to lay eggs until the temperature rises to 17°C. in summer or 15°C. in winter. Larvae are inactive at temperatures below 20°-22°C.

For the completion of each stage in its life-cycle, (i.e., the hatching of the egg, the development of a larval instar, the maturation of the pupa and the emergence of the imago) an accumulation of a certain total amount of heat is necessary. If the mean daily temperature is low metabolism is slower and the period of complete development of the stage is longer than when the mean daily temperature is high. As a general rule the total life-cycle of a species is longer at low temperatures approaching the critical minimum point and shorter at high temperatures approaching the optimum.

The seasonal histories of *Hyblaea puera*, p. 608, *Hapalia machaeralis* p. 674, and *Hypsipyla robusta*, p. 683, illustrate the variation in the lengths of stages of successive generations throughout a year.

High temperatures: When the critical point or upper vital

limit at the maximum of the effective temperatures is passed the insect relapses into a state of coma. As this occurs in nature ordinarily during the summer and hot weather seasons the condition is termed *aestivation* (or summer sleep). In the temperate climates and mountainous regions of India the summer is the period of optimum activity and aestivation scarcely ever occurs. But in the Indian deserts and the hot regions of the plains and the peninsula aestivation is for some species the normal means of passing the hot weather.

E.g., *Hapalia machaeralis* and *Hyblaea puera* aestivate during the hot dry months in central and western India, whereas they are active in the cooler and moister summer climate of south India. *Plecoptera reflexa*, on the contrary, is a species that does not aestivate but remains active throughout the dry hot weather of the Punjab plains (p. 654).

At temperatures below that inducing aestivation the insect may be active but its fecundity may be nil or much reduced, and in consequence its abundance is greater in those seasons and in those parts of its habitat where the temperature approaches the optimum. The Pink Bollworm of Cotton (p. 593) is a pest in the south-eastern, submontane and central regions of the Punjab while in the canal colonies and western cotton growing districts it is scarce.

The high fatal temperature at which practically all species of insects are killed instantly is about 60°C. Dry wood-borers such as *Lyctus* and *Anobium* are killed at 54°C. There are, however, certain thermophilous forms that regularly withstand high temperatures, e.g., cicadas sing in the sunshine when the shade temperature is 50°C. In deserts where the surface temperature may rise as high as 84°C. Orthoptera exist and are still active when their body temperature rises to 50°C.

High temperatures below the fatal maximum, if continuous for a period of a few hours, eventually cause death. The ground-temperature and the temperature of stationary objects is often very much higher than air-temperature (20-50°C.), consequently insects living in fixed positions and unable to move to cooler spots may have to endure very high temperatures. Thus, many species of bark boring larvae in logs are killed if the logs lie exposed to the direct radiation of the sun, but develop unharmed if the logs are lying in the shade.

The differences between the temperatures within a forest (eco-climate) and the general climate are not as great as might be expected. Forest canopy tends to be hotter by day and cooler by night than the general climate. But below the canopy of high evergreen or subtropical forest the day maxima are 3° to 4° C. less than those of the general climate.

Humidity.

As for temperature there is for each insect species a range of atmospheric humidities within the limits of which metabolism, activity and development are possible, and extremes at which death occurs and intervening zones in which the insect is dormant. The fatal zones are less clearly marked than in the case of tem-

perature. Relative atmospheric humidity can scarcely be considered without reference to the corresponding temperature for the maximum, minimum and optimum degrees of humidity for an insect's stage will vary according to the temperature and vice versa. A simple way of forming a mental picture of the combined influences of temperatures and humidity is to construct a graphical diagram in which the horizontal scale represents the mean temperature range and the vertical scale represents the mean relative humidity range; the boundaries of the successive zones of metabolic activity will be curves, and if the zones are restricted by short ranges of temperature and humidity the curves will be found to form concentric ellipses. Fig. 57, p. 178, shows such a graph for the longevity of beetles of *Hoplocerambyx spinicornis*.

Body-fluid: Humidity may affect an insect by altering the quantity of free water in its body. If the amount of body-fluid is above the optimum quantity, a dry atmosphere will evaporate the surplus and in consequence the rate of metabolism will return towards the optimum and the life-processes will proceed more quickly. An excessively humid atmosphere will prevent excess evaporation and the rate of metabolism will thereby be decreased, prolonging the period of development of the stage or dormant condition. Air sufficiently moist to impede evaporation permits the water-content of the body to rise toward the optimum and so increases the rate of metabolism. These effects are most pronounced in insects that do not drink and are dependent on the water produced by tissue-reactions for their body-moisture. Insects actively feeding on an abundance of succulent food are not greatly affected by large differences in atmospheric humidity.

The larva of the drywood borer *Stromatium barbatum* (p. 209) is dependent for its water-supply on the moisture-content of the wood in which it bores. If the optimum amount is obtained the life-cycle can be completed in one year; if it is insufficient, or is available only at short periods when the wood temporarily absorbs moisture from the air, the life-cycle is prolonged, and for as much as ten years. Some longicorn larvae like *Hoplocerambyx* can lose large amounts of body-moisture, e g, 65 percent, before succumbing; they can also pupate successfully in a saturated atmosphere with free moisture present. Shothole and pinhole borers (Platypodidae and Scolytidae) on the other hand can develop only in fresh sappy timber and cannot exist at all in dry or seasoned timber.

Oviposition, incubation and swarming of the lac insect, *Laccifer lacca* (p. 752) are not affected by humidity between 58 and 100 percent; heat is the governing factor. But the progeny of lac grown under humid conditions has a higher percentage of males than that grown under arid conditions.

By precipitation is understood the fall of snow, hail and rain. The effect of **snow** is that of its low temperature as already discussed in a preceeding section (page 799). Its mechanical effect as a barrier, etc., does not arise as soil-insects under snow are dormant.

One effect of **hail** as well as of heavy **rainfall** is mechanical. Young caterpillars or beetles and their larvae feeding exposed on

the surface of foliage are beaten or washed off and either drowned or injured so that they do not regain the crowns of trees.

The defoliation of teak by caterpillars of *Hyblaea puera* ceases entirely in heavy monsoon rains; whereas hardier defoliators of teak such as grasshoppers and cockchafer beetles, that can withstand the beating of rain or can rapidly escape to sheltered places, are able to survive a succession of rainstorms. Rain at the time of the swarming of the larvae or the emergence of the males of the lac insect, *Laccifer lacca*, may wash away and destroy a large proportion of them before they have settled or have reached and fertilised the females.

A secondary effect of rainfall is increase in atmospheric humidity. In regions where there is a marked monsoon-season separating a dry hot weather and a cooler autumn there is a marked seasonal differentiation in the emergence-periods of insects living a sheltered larval life and an exposed imaginal life, such as soil-insects and wood-borers.

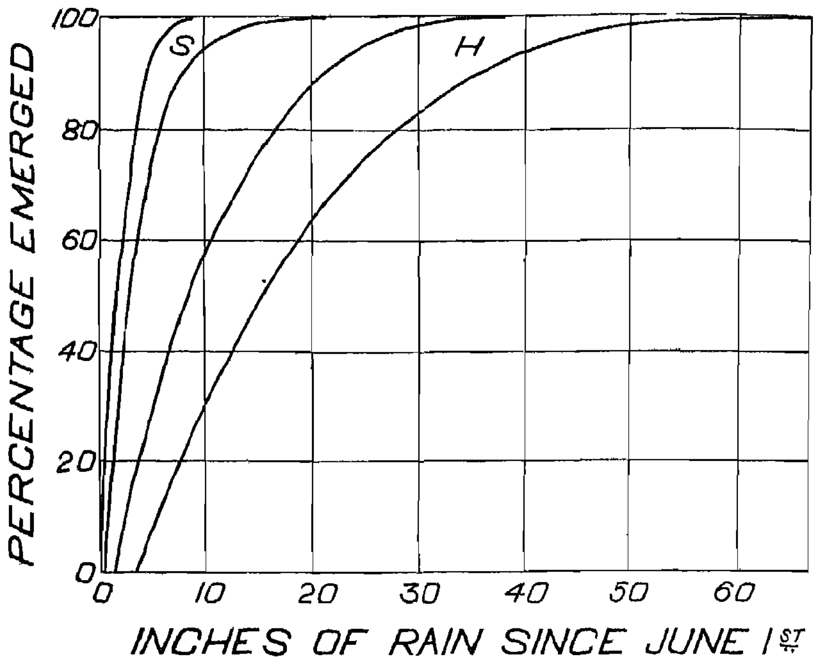
The swarming of the winged adults of subterranean termites is stimulated by rainfall. *Termes obesus* and *T. feae* swarm at the break of the monsoon; *Heterotermes indicola*, a wood-inhabiting species, swarms in the early monsoon showers. *Termes parvidens* swarms with early spring showers. Many chafer beetles of the groups Rutelinae, Melolonthinae, Cetoniinae emerge from the soil at the beginning of the monsoon. Among the wood-borers many species of Cerambycidae and Curculionidae complete their life-cycles and emerge with the beginning of the monsoon. *Hoplocerambyx spinicornis* commences its emergence-period with great regularity at the break of the monsoon and continues to keep pace with the subsequent rainfall according to its quantity and distribution [p. 183, figs. 58, 59]. In the active beetle-stage it is also very susceptible to atmospheric humidity; dry air is fatal both to the beetle and to its egg [fig. 57]. *Stromatium barbatum*, p. 209, emerges with much less accumulated rainfall than *Hoplocerambyx*; a comparison of the behaviour of the two species is shown in fig. 196.

A further indirect effect of rainfall through the production of high humidity coupled with high temperatures lies in the favourable conditions for the outbreak and spread of insect-diseases due to viroses, fungi and bacteria, and the encouragement of digestive troubles. Many caterpillar outbreaks are brought to an end by this combination of control factors.

Wind.

The effect of wind is twofold, mechanical and evaporative.

Transport: A strong wind, which violently agitates foliage, blows insects off their food-plants and thus may prevent delicate forms from regaining safety and food. Far more extensive is the effect of wind on the dispersal of insects. Cyclonic winds pick up insects and carry them for great distances before they are deposited, but convectional currents and moderate wind-velocities are the more important in the aerial transport of insect life. Convectional currents lift flying insects to very considerable heights, certainly as far as 15,000 feet above sea-level. By means of kites flown with nets attached and of aeroplanes fitted with traps much has been learned of the insect population of the air. In the terrestrial zone of the atmosphere (up to about 200 feet) the insect population is most abundant and includes those forms that are



Rainfall and emergence of cerambycid beetles.

Fg. 196. Graph showing correlation between the number of inches of rain fallen since June 1st and the percentage of the total annual population of beetles emerged. The two pairs of curved lines represent the gradient of quickest rate of emergence (upper) and slowest rate of emergence (lower). The right hand pair, **H**, refers to *Hoplocerambyx spinicornis*, the left hand pair, **S**, refers to *Stromatium barbatum*. Thus with 10 inches of rain, for example, 97 to 100 percent *Stromatium* emerge, and 30 to 59 percent *Hoplocerambyx* emerge.

strong fliers or heavy-bodied and by reason of their strength and weight are able to resist the upward convection-currents. In the upper air or plankton zone, which stretches from 200 ft. to 14,000 ft. or more, is found a considerable population of small-bodied, weak-flying forms which float or drift in the air at the mercy of wind movement and vertical convection-currents. Their numbers reach several millions over a square mile of ground; it has been calculated that the number drifting past in one hour across a plane surface 1 mile wide and 100 yards high is over 50 millions. The composition and seasonal abundance of the aerial insect population caught on sticky traps in sandal forests in south India are given in *Ind. Journ. Ent.*, I, 1939, pp. 15–25 and in *Ind. For. Rec.*, Ent., VI, No. 4, pp. 172–181.

Wind-transport is therefore responsible for the dispersal of many species of insect pests not only in the winged stage but also

as newly hatched larvae (e.g., Lymantriidae, Psychidae). Spiders are carried by means of their gossamer. The rapid spread in India of *Ophiomyia lantanae* (p. 416) and the colonisation of shisham plantations in the Punjab plains must be assigned to aerial currents.

The flight-range of insects is a question that intrigues foresters who require some indication of the area of a safety-belt or other territorial barrier to the movement of pests of trees. The normal flight-range, whether it be a few furlongs or miles, is however mainly of academic interest, since it is liable to profound modification by the climate of the locality as well as by abnormal weather conditions. Locusts, migrating butterflies, hawkmoths, etc., cover hundreds of miles by deliberate flight,—not necessarily at one stretch although moths have appeared on ships three or four hundred miles from land. A combination of short flights and wind-transport is sufficient to explain the arrival of pests on trees scattered individually throughout leagues of mixed forest; or of mosquitoes in a rest-house 2–3 miles from the breeding-place.

Evaporation: Wind carries the odour of food-substances and assists insects to locate their food over greater distances than they can in still air. *Hoplocerambyx spinicornis* is able to discover a freshly felled sal tree in the course of a few minutes if a stiff breeze is blowing, and flies upwind towards it; the effect of the odour may extend for at least half a mile. *Pagiophloeus longiclavis* (Curculionidae) may travel 4 miles in search of its food,—newly dead bark of *Cedrela toona.*

Wind-movement increases evaporation and encourages the radiation of body-heat, and the desiccation or reduction in temperature may be inimical. Hot winds blowing in April and May seriously damage lac encrustations on the twigs of the host-tree. The females of *Laccifer lacca* are killed and dried up and the lac may be melted and run.

Light

Sunlight: The reactions of insects to sunlight and shade are not entirely separable from the effect of temperature. Many adult insects are distinctly sun-lovers and are active in bright sunshine, remaining inactive when the sky is overcast although the air-temperature is equally high at both times, e.g., butterflies, and the brightly coloured buprestid and cetoniid beetles. The effect of sunlight as opposed to shade is traceable in the oviposition habits. *Xyleborus minor* prefers to bore into logs of *Shorea robusta* lying in the shade and avoids those in sunlight. *Cedrela toona* and *Swietenia macrophylla* are less liable to attack by the shoot-borer *Hypsipyla robusta* (p. 686) when grown under slight overhead shade than when grown in the open. Sunlight has a decided effect on the distribution of insects and other animals in tropical

rain forest; the fauna inhabiting the canopy 100 to 150 feet above ground is composed of many species that do not occur in the darker under-storey level or at ground-level.

The Moon: Mixed up with the religious ideas of nearly all primitive peoples are superstitions regarding the influence of the moon on the growth and other activities of plants and animals. Several beliefs are prevalent in India that the moon in her phases is able to influence the activity of certain insects, as for example timber-borers. The waning of the moon has been regarded, both in ancient and modern times and in many lands, as the proper season for the felling of timber. During the wane of the moon the sap is believed to flow down leaving the wood dry and more likely to season quickly, whereas the waxing moon is supposed to draw the sap up. On the same principle injurious insects are considered to be more abundant during the waxing and full moon. A study of the emergence-periods and swarming of borers shows that such beliefs are erroneous. The liability of bamboos to attack by *Dinoderus* spp. (Bostrychidae) is supposed to be high if the bamboos are cut during the period of moonlit nights and low if cut on days with dark nights (and occasionally the opposite is believed); actually the date of felling with reference to the moon's phases has no correlation with the intensity of the attack. The swarming of the lac insect is supposed to be connected with the phases of the moon, but actually it may occur any time up to four weeks later in one year than in another.

On the other hand the activities of certain aquatic organisms are definitely lunar in their periodicity. Mayflies (Ephemeroptera), especially species living in the clear and shallow waters of hill streams in India, usually swarm for a few days before and after the full moon, whereas caddis-flies (Trichoptera) appear to swarm only on dark nights

Dispersal

The dispersal of animals differs in important features from that of plants. Animals are endowed with powers of movement which are employed usually for purposes of feeding, finding mates and escaping enemies; plants are immobile but ensure dispersal of seeds, and thereby the survival or spread of the species, by means of special adaptations for the purpose. In both there is an inherent tendency to enlarge the area inhabited, so that no environment capable of supporting life remains unoccupied. Animal dispersal is on the whole a rather quiet, humdrum process, taking place all the time as a result of the normal life of animals (Elton). Nevertheless it may result automatically in the spread of the species through the three phases of dispersal, establishment of the individual and establishment of the species; the area covered by it at any one time is its distribution. Elton sums up these terms as follows:—

Dynamic	Dispersal Establishment of the individual Establishment of the species	Spread
Static	Distribution	

Methods of dispersal: In addition to the normal movements of individuals the dispersal of insects is achieved (a) by broadcasting of eggs or young, or (b) by migration, or (c) by accidental transport; (d) ecological succession, i.e., changes in the nature and extent of the environment, also result in slow dispersal.

(a) The female of *Phassus malabaricus*, p. 603, scatters thousands of eggs in flight. The newly hatched caterpillars of *Lymantria obfuscata*, p. 639, and *Clania cramerii*, p. 669, are largely dispersed by wind. The first stage larvae or triungulins of meloid beetles are produced in great numbers on the chance of being transported by bees. The female of *Podomyia setosa* (p. 453) lays eggs abundantly on leaves in the expectation that they may be eaten by caterpillars. Broadcasting of this nature involves an enormous wastage of life.

(b) Migration by flight in swarms is a characteristic of many butterflies (see Pieridae) and locusts (see Acridiidae), and birds.

(c) Accidental transport by floating logs, trees, etc., disperses wood-borers. The various processes of harvesting, exploitation of forests, transport of raw materials and manufactured products, etc., are important factors in dispersal. Transport by aerial currents (wind-dispersal) is discussed on p. 803.

(d) Ecological succession, whether the result of natural changes or of human intervention, alters the range of a species of insect and its population-density. In the transition zone of *Pinus longifolia* and submontane deciduous forests the effect of annual climatic variations on the plant-succession periodically causes invasion of the pine forests by the bagworm *Clania cramerii* (p. 669), which is primarily an associate of broad-leafed plant-communities. A plantation of *Dalbergia sissoo* made in the arid plains of the Indus offers a new environment which is colonised by scores of species of animals in the course of a few years. Practically all the ordinary silvicultural operations affect the numbers and dispersal of species in the insect communities in a forest.

Barriers to dispersal and distribution

Animals vary greatly in their ability to cross barriers to dispersal. The differential effect of barriers and highways on the spread of species has determined their distribution and defined the faunal regions. To terrestrial animals the oceans and seas offer the most effective barriers. Rivers as large as the Ganges and the Brahmaputra are of much less importance and there is often no difference in the fauna of their opposite banks; small rivers and lakes make only temporary obstacles. High mountain ranges are ordinarily impassable; the Himalayas with the Tibetan plateau have formed a complete barrier to the advance of palaearctic species of insects from Central Asia to subtropical India. The deserts of Sind and further west present another type of barrier; and in a minor degree the modern deforested Gangetic plain constitutes a similar obstacle. Flying animals and wind-borne insects are least limited by topographical and climatic barriers. Nevertheless the range of many species of insects stops short where there is no immediately obvious barrier to their spread and one therefore has to search for other explanations of

the restriction. Historical zoogeography is able to throw light on the origin of such conditions.

A knowledge of faunal regions, the original home of a species and its present distribution is of more than academic value. It is a matter of practical importance in view of the increasing possibilities for the artificial spread of pests past barriers to distribution,—possibilities which are facilitated, on the one hand, by commercial intercourse, trade and transport, and, on the other hand, by extended cultivation of food-plants and introduction of exotics. It is also of fundamental value in problems of biological control and determines practicability of introducing foreign parasites and predators for the control of pests.

Zoogeographical distribution

The distribution of life on earth is not explainable in terms of the present extent of land and sea and topographical barriers. It is known that changes in these features have occurred in previous geological periods and that the sequence and magnitude of these developments have affected the distribution of plants and animals. The world is divided into six faunal or zoogeographical regions, viz., Nearctic, Palaearctic (both sometimes combined as Holarctic), Neotropical, Ethiopian, Oriental and Australasian Regions. In each of these Regions the fauna is more or less homogeneous, at any rate for certain well-studied classes of animals; they are, however, not rigid conceptions and their boundaries are not valid for all classes, but are varied according to the opinions of zoologists who give greater emphasis to a particular group of animals. It is obvious that animal groups as diverse as carnivora and predaceous arthropoda, aquatic and soil-inhabiting (terricolous) animals, birds and plant-eating insects, etc., are limited in their distribution by different environmental factors. The geographical distribution of the vertebrates has received closer study than that of the invertebrates (and particularly of insects) hence the delimitation of Regions and their subdivisions has been based primarily on the distribution of vertebrate groups and especially the pioneer deductions of Blandford, Sclater and Wallace.

The area inhabited by the fauna biographed in this book includes part of the Palaearctic and Oriental Regions, as defined primarily by vertebrate zoogeographers. Subdivision of these Regions in order to define areas appropriate for the Insecta raises several problems; it has been attempted for a meagre number of groups, e.g., ants by Forel, mosquitoes by Christophers, butterflies by Evans, insects of tropical India by Lefroy; and their conclusions are not entirely in accord. The distribution of plant-eating insects has been determined primarily by the geographical occurrence of their food-plants, but, contrary to what one might conclude at first thought, the distribution of an insect does not always coincide with that of its food-plant; the

insect may occupy only a part of the habitat of one plant-species or may extend beyond it with alternative food-plants. Indian botanists and foresters regard the distribution of forests from two view-points, (a) the floral or phytogeographical regions and (b) the composition of forest types. For details of the former Calder who defines 6 major divisions in India, Brandis who recognises 7 divisions, and Troup who lists 12, may be consulted. For a classification of Indian forest types see Champion, 1936.

Entomologists have so far not produced a comprehensive survey of the insect faunas in the Indian and adjoining territories (Lefroy's survey is restricted to what he terms tropical India), nor has the ecological study of insect-communities progressed appreciably. The following subregional classification of the predominantly herbivorous insect fauna of the forests of the Indian area is based on the writer's impressions rather than on statistical analyses of characteristic families.

PALAEARCTIC REGION	ORIENTAL REGION
1. Northwest Indian Subregion	3. West Himalayan Subregion
2. Tibetan Subregion	4. Peninsular Indian Subregion
	5. South Indian and Ceylonese Subregion
	6 Indo-Chinese Subregion
	7. Malaysian Subregion.

PALAEARCTIC REGION

In the geographical area under consideration the portions assigned to the Palaearctic Region are mainly desert or mountainous; they comprise an eastern extension of the Mediterranean Sub-region and the southern zone of the Central Asian Subregion.

1. **Northwest Indian Subregion:** includes Baluchistan, the North West Frontier Province, Hindukush and Karakoram Mountains, the Indus Plain, Sind Desert and Western Rajputana to the Aravallis. (Except in the truly desert tracts the herbivorous insect fauna of the last 3 districts has been profoundly modified and dominated by agriculture and plantation forestry which has increased the Oriental elements).

2. **Tibetan Subregion:** Tibet and the inner ranges of the high Himalayas.

ORIENTAL REGION

3. **West Himalayan Subregion:** from Kashmir to Kumaon (The fauna of Nepal is not well-known and the boundary between the West Himalayan Subregion and the Indo-Chinese Subregion falls within its territory).

4. **Peninsular Indian Subregion:** from the south of the Himalayas to the Brahmaputra River, the Gangetic Plain, the Western India Plains, Central India, Orissa, the Deccan to about 15° Lat. This subregion has been variously divided by several zoologists, but it is not a unit of zoogeographical value being

largely transitional to neighbouring subregions; for satisfactory treatment numerous subdivisions are desirable, e.g.,

(a) Gangetic Plain, West (c) Central India
(b) Gangetic Plain, East (d) Chota Nagpur
(e) Deccan

5. **South Indian and Ceylonese Subregion:** The Western Ghats and West Coast, Coorg, Nilgiris, Anamallais, Palnis, Travancore and the mountains of Ceylon; the adjacent plains of the Carnatic and Ceylon. Subdivision is mainly by altitude, e.g., (a) The Mountains, (b) The Plains.

Indo-Chinese Subregion: The Eastern Himalayas from East Nepal to Indo-China and the Isthmus of Kra. Its subdivisions are:—

(a) Eastern Himalayas to the Dihing gap
(b) Trans-Himalayan Tract. Assam east of the Brahmaputra, Burma, Southern Yunnan, Northern Indo-China, Northern Thailand
(c) Indo-Chinese plain, including the dry lowlands of Burma, Thailand, Cambodia
(d) Andamans

The Sundarbans and the coastal mangrove forests may be regarded as outliers of the Malaysian Subregion.

7. **Malaysian Subregion:** From about 12° Lat. in Tenasserim, the Malay Peninsula, the East Indian Archipelago to the limits of the Oriental Region excluding the Philippine and Austro-oriental subregions. Its subdivisions are:—

(a) Tenasserim and Malaya
(b) Nicobars, which are approximate to Sumatra (etc.)

Within these Subregions the insect fauna, like the flora, is strongly conditioned by elevation and local climate. Lefroy considered the whole of British India below 2,000 feet to be tropical, and denoted the moister forested slopes of the hills between 2,000 and 6,000 feet as subtropical. Champion classifies the forest types of India through four zones, tropical, subtropical, temperate and alpine, each subdivided on available moisture as reflected by the relative importance of evergreen, deciduous and thorny trees. In the southern subdivisions true alpine formations are absent.

The uneven distribution of the species of a group in the different subregions is illustrated by the Butterflies. Out of a total fauna of 1,443 species the proportions are :—

N. W. India	W. Himalayas	Peninsula	Ceylon	N. E. India	Burma	Andamans	Nicobars	Subregions
285	421	315	238	853	1014	170	94	Species.

The following examples illustrate different types of distribution of species of forest insects through one or more subregions:

Xyleutes ceramica (Cossidae). Ceram and the Philippines to Java and Burma and not crossing the divide into India.

Dihammus cervinus (Cerambycidae) Japan to the western parts of the Indo-Chinese subregion and not crossing the Gangetic plain.

Hoplocerambyx spinicornis (Cerambycidae). Philippines, Borneo through the Indo-Chinese subregion into Central India but not further south.

Sarcophaga fuscicauda (Calliphoridae). North Queensland through Malaya, Burma, Himalayas to Dehra Dun; Andamans, Ceylon and West Coast to Bombay.

Crossotarsus minax (Platypodidae). Ceylon and South India.

Calopertha truncatula (Bostrychidae), North Africa and Arabia into North-west India but not beyond.

Sinoxylon sudanicum (Bostrychidae). North Africa through North-west India, the Peninsula to the South Indian subregion.

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2. NUTRITIONAL CONTROL

FOOD-SUPPLY

THE primary driving force of all animals is the necessity of finding the right kind of food and enough of it. Food is the burning question in animal society, and the whole structure and activities of the community are dependent upon questions of food-supply (Elton). The nature of the food-supply is one of the most important factors determining, firstly, the existence and, secondly, the abundance of a species in an area. The effect of food may be considered from the aspects of (i) its quality and (ii) its quantity.

i, Quality of food-supply

The chief factors in quality are (a) the maturity of living plant-tissues and the freshness of dead tissues, (b) the existence

of alternative supplies of food, and (c) the resistance or immunity of the host.

(a) Maturity of plant-tissues

An insect that feeds on the foliage of a tree or on its bark and wood or sucks its sap does not necessarily subsist on food of the same quality throughout its life-cycle. The food-requirements of the early larval or nymphal stages may be different to those of the later stages, and both may differ from those of the imago. If a species is to develop normally and to survive it must find the right kind of food at the right time in each stage of its existence.

Defoliators: The first instar of a defoliating caterpillar immediately on hatching from the egg usually requires much more tender foliage than do the later instars, and if the right kind of food cannot be obtained it dies of starvation. Weather conditions do not necessarily affect an insect and its food-plant to the same extent; weather may cause the early or late appearance of the insect when the food suitable for its particular instar is not avilable.

Plecoptera reflexa, p. 654, requires quite young leaf-tissue on hatching from the egg and is unable to eat the older tougher leaf that forms the normal food of the later larval stages. *Hyblaea puera*, can start its larval life only on tender unexpanded leaves, whereas *Hapalia machaeralis* can complete its whole larval life on mature teak foliage (p. 681). In the cultivation of mulberry silkworms the age and condition of the foliage supplied affects not only their rate of growth but also their susceptibility to flacherie disease (p. 567).

Borers: The bark-boring fauna of felled or fallen trees, consists primarily of species that can establish themselves only while the bark is fresh. They must either complete their life-cycles rapidly while the bast and cambial zone remains fresh, or they have longer life-cycles and a change of food-material in the later instars. In both classes fresh bark is essential for the establishment of the brood and trees that have fallen or have been felled long enough before the swarming-dates cannot be utilised for oviposition. If the quality of the food deteriorates during the larval period it is fatal to a very specialised species, but a more tolerant species may linger on. *Polygraphus longifolia*, p. 380, has a normal life-cycle of about 3 months yet may survive for a year in old dry bark of pine.

The quality of the food decides whether larvae of the Pink Bollworm of Cotton, p. 593, will pupate normally or will enter into a diapause as long-cycle larvae which do not pupate for many months. As the cotton crop ripens more and more larvae are forced to feed on mature bolls with a low moisture content in the seeds. The dry food inhibits pupation.

A quite different insect-fauna colonises bark and wood that is no longer fresh but has passed through stages of decomposition; the rate of development of borers of this class is influenced by

the presence of wood rotting fungi, ingredients like starch, and the moisture-content of the wood.

Warm moist conditions, in themselves favourable for fungal attack, combined with the presence of decay in timber are particularly suitable for the rapid development of the Death-watch Beetle (Anobiidae, p. 40). Warm dry conditions and the absence of decay are unfavourable and prolong the life-cycle for several years.

The relative proportions of starch to wood-tissue affects the rate of growth of larvae of *Lyctus*, *Dinoderus* and other Bostrychidae; if the starch content is low the larvae either die off or take several years to reach maturity.

Sap-suckers: Insects that suck the sap of plants ordinarily feed on soft and easily penetrable tissues when young, though in later stages they may be able to deal with a more hardened epidermis.

Urostylis punctigera, p. 773, feeds in the early instars on leaves of *Michelia champaca* and later moves to the branches and main stem. Young lac insects, *Laccifer lacca*, on emerging from the cells of their mothers that are on twigs of *Acacia catechu* 6–9 months old, wander in search of new shoots; if the host-tree does not produce any suitable shoots for the larvae of second brood they die.

(b) Alternative food-plants

Many species of forest insects are polyphagous, i.e., normally feed on a very considerable and not necessarily related series of food-plants; the plants other than the principal species are termed alternative food-plants. Others have a much more restricted dietary that comprises a few, usually related species food-plants; these are termed oligophagous. Insects feeding on one species of plant are termed monophagous. The socalled "botanical instinct" whereby a species of insect selects for its larval food a particular species, genus or even family of plants is probably a reaction to the odour of the plant and also to its taste which is closely connected with odour. It is certainly possible to deceive insects as to the nature of a substance by disguising it with the essential oil of their true food-plant.

A monophagous species of insect is restricted in its distribution to the habitat of that tree. It may accompany the tree when the latter is planted artificially outside its habitat, but more often than not a monophagous insect does not occur throughout the natural habitat of the host-tree because it is limited by other control-factors. (e g., *Xyleutes ceramica*, the beehole borer of teak, p. 573).

Oligophagous and polyphagous species may be but are not necessarily found wherever any of their alternative food-plants grows, since other factors can be more decisive. The occurrence of 2 or more alternative food-plants in the same locality affects

the abundance and population-density of a species and can determine whether or not it becomes a pest. Consequently, the composition of mixed forests or plantations is a fundamental factor in Silvicultural Control, q. v.

The nutritive quality of alternative food-plants affects the rate of development of an oligophagous insect. Caterpillars of *Hyblaea puera* grow most quickly on *Vitex negundo* and slowest on *Tectona grandis*; the rate of growth on *Premna latifolia* is intermediate (p. 615).

Biological races: In some polyghagous species the broods feeding on one of the host-plants develop a tendency to prefer that food-plant to the others, and, if there is any choice, the progeny will always resort to the same food-plant as the parents, though in cases of necessity they can survive on other food. This tendency may eventually become fixed so that the insect is permanently restricted to one food-plant; such insects are termed biological races. The border line between a biological race and a true monophagous species is usually rather vaguely marked morphologically, often only by slight differences in size or colour. Perhaps many monophagous species originated as biological races. The shothole borer of tea, *Xyleborus fornicatus* (Scolytidae), feeds on the castor-oil plant and on many kinds of forest trees in India, but in the tea gardens of Ceylon it attacks the living tea-bush and has developed a biological race in tea, named *fornicatior*. In south India this biological race has come into existence in the last 20 years and is not yet fixed (p. 396).

The lac insect has two main strains or biological races, the kusmi and the rangeeni (and probably several substrains) that are associated with different food-plants.

The food-plant of the kusmi strain is *Schleichera trijuga*; its lac is of better quality than that produced by strains living primarily on other hosts; its life-cycle is characteristic. When the kusmi race is grown (by artificial inoculation) on other food-plants it retains its characteristics for some generations but if grown continuously on other hosts it eventually deteriorates and dies. The rangeeni race will not live on *Schleichera trijuga* but thrives on several other food-plants.

Some of the lac individuals growing on *Zizyphus jujuba* in a particular locality, (Jodhpur), produce brilliant yellow lac-cells which differ from the red lac grown on the same host-plant elsewhere. Lac growing on *Acacia catechu* is more succeptible to attack by parasites than is lac growing on *Zizyphus jujuba*. *Shorea talura* gives rise to a strain of the lac insect in south India that has 3 generations in 13 months, whereas 2 generations a year is the normal for all other host-plants.

(c) Host-resistance

One of the most important factors in environmental resistance is the physiological condition of the host. Some degree of resistance to insect-attack is possessed by practically all forest trees. It may be (a) of a general nature—a state of unpalatability to all

indigenous insects; some of the ultimate reasons for this may be geological or hereditary. Or (b) it may be resistance to all but a few species of insects; this is the normal condition in natural or virgin forests where insect attack on healthy trees is rarely serious or fatal; a state of equilibrium exists preserving both the flora and the fauna. Or (c) the plant may be totally resistant, or immune to the attack of a particular insect-species only when in a particular physiological condition, i.e., its endurance is a variable quality depending on external conditions. Disease-resistance seems to be the natural reward of healthy and well nourished protoplasm. The variations which give rise to resistance are:—

(a) Physico-chemical, such as hardness of the epidermis of the leaf or shoot or seed, the presence and size of vessels; the presence of essential oils, acids, gums, resin, latex, etc.; sap-reaction and sap-density.

(b) Physiological, such as seasonal adaptation resulting in earliness or lateness in flushing, fruiting or leaf-fall; vigour permitting the outpouring of gums, oleo-resins, etc., the healing of wounds, ability to produce a second or more flushes of foliage after defoliation; rapidity of growth allowing a rapid passage through periods of danger.

These factors have been well studied in cultivated plants and use has been made of them in selecting and propagating immune varieties and by hybridisation, but we are only just beginning to know something of them in the forest trees of India. It is nevertheless evident that the resistance of growing trees is proportional to the vigour of growth. Weaklings are more susceptible than the stalwarts. A. Howard goes so far as to dogmatise that insects and fungi are not the real cause of plant-diseases and only attack unsuitable varieties or crops improperly grown. It is contended that a proper condition of soil-fertility increases the inherent resistance to disease. Pests and diseases are really censors or indicators of crops that are imperfectly nourished.

Crop-nutrition and soil-conditions: The response of a plant to insect-injury is affected by excess or deficiency of certain food-materials essential to the plant. Similarly the degree of insect-damage is determined by the effect of particular soil-conditions on the plant. Crop-nutrition and soil-conditions are subjects of investigation by a specialist branch of plant-physiology with which the economic entomologist must acquaint himself in order to devise methods of pest-control by regulating the nutrition of crops.

Tea-growing in India and Ceylon provides two illustrations of the influence of differential nutrition on host-resistance. (a) The Shothole Borer, *Xyleborus fornicatus* (p. 395), bores into the stem and branches of the living tea-bush in Ceylon; the tunnels and holes weaken the wood so that the branches readily break off under the pressure of strong wind or the movement of coolies at work on plucking and hoeing. The holes heal up more quickly and the branches are less brittle if the soil is manured so as to increase its nitrogenous content. (Jepson and Gadd). In Assam

the tea Mosquito Bug, *Helopeltis theivora* (p. 737), is a persistent enemy of tea causing it to "shut up". When a constant supply of soluble potash is directly applied to the roots of the bushes and the bushes are able to utilise the added potash, they are freed from the pest and remain free for the rest of the season. Comparative immunity from attack accompanies an increase in the proportion of potash to phosphoric acid in the leaf (Andrews).

The development of *Laccifer lacca* (Coccidae) on *Schleichera trijuga* is affected by the sap-reaction of the tree. The variety (or biological race) of *S. trijuga* known as 'charka' has a pH value of 5·4 to 5 8 and if infected with lac produces only a poor crop. By injecting an alkali such as ammonia and lime the acid sap-reaction of 'charka' is neutralised and the lac insect is provided with more favourable conditions for development. (Glover).

The following examples illustrate physico-chemical or physiological types of resistance, either singly or combined.

i. Borers and resin, latex, etc. When the living sal tree is attacked by *Hoplocerambyx spinicornis* (p. 181) eggs are laid in crevices in the bark and the larva bores down towards the cambium-layer; a healthy tree resists this attack by an outflow of resin, (*ral* or *dammar*), which flows into the larval tunnel and drowns the larva. In a less vigorous tree the resistance may be less, or unevenly distributed, so that in one part of its long bole the *spinicornis* larvae may be all killed and embalmed, while in another part the larvae are successful, perhaps by force of numbers, and establish their galleries in the sapwood. In the same way many species of shothole borers of the genera *Xyleborus* and *Platypus* when attempting to bore into healthy living trees of dipterocarps or figs or other species producing a gum or latex, are successful only in the neighbourhood of wounds where the exudation is restricted.

The conifers in the Himalayan forests, that are frequently ravaged by fires, are unusually resistant to the attack of bark-beetles; these can first establish their broods only in parts of the bark that has been killed or so seriously scorched by fire that the resin-ducts are out of action. In the western yellow pine forests of North America, on the other hand, the formation of volatile oils (aldehydes or esters) which are by-products of a respiratory fermentation or abnormal enzyme activity in subnormal trees, is sufficient to cause an initial weak attraction to the bark-beetles, *Dendroctonus brevicornis*. Beetles from the immediate vicinity bore into the bark and introduce a yeast which produces a fermentation strong enough to attract other beetles from a wider radius.

ii. Termites: The immunity to attack by termites that is possessed by the timber of *Cedrus deodara*, *Cinnamomum camphora*, *Michelia champaca*, *Shorea robusta*, *Tectona grandis* and other species is not due to the hardness of the wood but to the presence of lignin or of oleo-resin, or of acid and bitter salts. *Dipterocarpus alatus* has a very hard wood but is severely attacked: *Artocarpus integrifolia* has a soft wood but is relatively immune. The presence of sesquiterpene alcohol is said to give

immunity to *Tectona grandis*. The normal wood of *Pinus longifolia* is attacked by several species of borers but the highly resinous stump wood (chilka) is entirely immune. Woods with a high lignin-content are very resistant or immune and those with a low lignin-content are most susceptible to termites.

iii. Lyctus and pore-size: Small-pored timbers are on the whole more resistant than large-pored timbers to the attack of powder-post beetles (*Lyctus*, p. 71) because the female beetle can lay her eggs inside only those vessels exposed on cut surfaces, the diameters of which are larger than the diameter of the ovipositor.

iv. Borers and callusing or coppicing power: Young saplings of *Gmelina arborea* and of *Tectona grandis* are both attacked at a tender age by *Dihammus cervinus* (p. 163) but the resistance of *Gmelina arborea* appears to be the greater. The latter tree forms no cankerous swelling at the point of attack as does teak, and the circulation of sap between the foliage and the root is thereby much less disturbed. The more rapid growth of the sapling in the course of its first 4–5 years carries it on to a size at which it is immune. A strongly growing teak sapling can kill the young larva of *Dihammus* by a proliferation of callus into the burrow, but a weakling may struggle for a time and uselessly form masses of callus in a large globular canker that eventually becomes a weak point at which the stem snaps off. [fig. 51].

Young growing *Acacia arabica* trees are attacked by *Celosterna scabrator* (p. 153). On unsuitable soil with a deficient water-supply the growth of the tree is intrinsically poor so that after the stem above ground has been killed the stump can only send out weak coppice-shoots, which are still less resistant. In better localities the attack is not fatal though the insect completes its life-cycle; it leaves a wound that subsequent years heal up.

v. Defoliators: Defoliation has a much more serious effect on evergreen than on deciduous trees. A pine such as *Pinus excelsa* recovers with difficulty from one complete stripping, while *Cedrus deodara* may survive defoliation for two or three years in succession; deciduous trees can withstand longer periods of repeated defoliation, and some species such as *Tectona grandis* and *Dalbergia sissoo* are able to put out a second and more flushes of leaves during one growing-season. The reaction of the tree in this respect has its effect on the abundance of the defoliating insect.

Dalbergia sissoo, as grown in pure stands in the irrigated plantations of the Punjab, is subjected to a succession of heavy attacks by *Plecoptera reflexa* (p 655) owing to the fact that it bursts into leaf again shortly after a complete stripping and in time to provide food for the next generation of the pest.

On the other hand a tree like *Gmelina arborea* if stripped early in the growing season by the defoliating beetle, *Calopepla leayana* (p. 223), re-

mains leafless for the rest of the season and the subsequent broods of the pest either starve or have to migrate elsewhere to undefoliated trees.

vi. Sap-suckers: Some species of trees exhibit resistance or susceptibility which indicates the existance of distinct biological races, but races which are not readily definable by botanical or descriptive characters.

Schleichera trijuga has two races, 'kareya' which is an excellent lac host, and 'charka' which produces a poor crop; 'kareya' has a neutral pH value, 'charka' has an acid value. *Butea frondosa* also has two races, one of which is an excellent lac host and the other will not take a lac infection. *Albizzia stipulata* occurs in two races, 'kala' on which the lac insect can reach maturity and 'safed', on which the larvae die after having settled for a few weeks (Glover).

The lac insect is not able to live on trees which show a very acid sap-reaction (pH 5·0 to 5·4) or a very alkaline pH value (6·2–6·8); the sap-reactions of species of trees on which it thrives approach a neutral value (pH 5·8 to 6·0). The sap-density of resistant species of trees ranges from 0·9 to 0·23, whereas that of susceptible species ranges from 0·14 to 0·17.

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ii, Quantity of food-supply

Every organism multiplies up to the limit of its food-supply, if allowed to by the other controlling factors of its environment. The latter, however, *may* be more powerful in their effects than the factor of food-supply alone.

Pure crops: In a pure formation of one species of plant, conditions for the multiplication of an insect feeding on it reach the optimum. The adult finds the food-material on which to lay its eggs with the least trouble and with the minimum reduction in its effective numbers by predators or exposure or failure to find a mate. The larvae of external feeders also find fresh feeding-grounds in the shortest time if the supply happens to get exhausted locally. In a mixed formation, on the other hand, not only is the total quantity of essential food less, but the other plants in the mixture offer physical obstacles to the discovery of it. In forests an even-aged pure crop provides the most uniform food-supply, but an uneven-aged pure crop may under certain circumstances have the same effect as a mixed forest, as, e.g., in the case of an insect attacking only the young trees or only the older trees. In consequence, pure even-aged plantations, and forests managed under the uniform system, are most liable to serious damage by major pests. E.g., *Xyleutes ceramica* (Cossidae), *Dihammus cervinus* (Cerambycidae), *Calopepla leaya-*

na (Chrysomelidae), *Plagiophloeus longiclavis* (Curculionidae), *Urostylis punctigera* (Pentatomidae) are plantation pests and are rarely injurious in natural forest where the host-trees are scattered. (See also section 4, Silvicultural Control)

Food-supply of borers: A local or temporary increase in the food supply of bark and wood boring insects may be caused by the action of other natural factors, such as the felling of trees by high winds or cyclonic storms, damage by snow-break and lightning, the injurious effects of land-slips, floods and fires, or dying-back due to fungous diseases, etc. Felling operations form an important source of extra breeding-material.

Competition for food: Competition for food and for the same feeding-space may take place between different species in an animal-community or between individuals of the same species; it is a regulatory factor that affects the abundance of a species and is economically important when the species is a potential pest. An extreme view considers competition to be the only factor capable of producing balance in populations.

Competition between species: Defoliators: Practically every species of important forest trees is attacked by an association or complex of defoliators.

Shorea robusta is the food-plant of caterpillars of several lepidopterous families of which perhaps Lymantriidae are dominant but it is unusual for any one species to be outstandingly abundant; only *Ingura subapicalis*, p. 652, which specialises in the new flush and has very few competitors, is truly epidemic in natural sal forest.

The defoliators of *Tectona grandis* include two groups, the skeletonisers and the whole-leaf-eaters. When skeletonisers like *Hapalia machaeralis*, p. 681, or *Diacrisia obliqua*, p. 561, are first to take possession of the leaf, their attack is not always followed by leaf-shedding; leaves with green patches (and towards the end of the growing-season even completely skeletonised leaves), are retained by the tree. When the whole-leaf-eaters such as *Hyblaea puera* or grasshoppers destroy the foliage, the tree puts out a new flush, which can be utilised by both groups of defoliators. Competition thus tends to favour the skeletonisers.

Dalbergia sissoo supports leaf-miners and leaf-rollers, as well as the dominant leaf-eater, *Plecoptera reflexa*; an extensive outbreak of the secondary miners or rollers under certain conditions acts unfavourably on the multiplication of *Plecoptera*.

Borers: In competition among bark-borers it is usually the larger stronger species that wins.

A log of *Shorea robusta* may be occupied by many broods of the bark-beetle, *Sphaerotrypes siwalikensis*, (p. 386), but if eggs are laid shortly afterwards by Cerambycidae, the longicorn larvae extend their galleries through the bark and sapwood and may completely destroy the colonies of the bark-beetle. The broods of shothole borers, *Diacavus*, *Platypus*, *Xyleborus*, etc., although in the depths of the sapwood and heartwood also suffer in competition with the longicorn borers, for their entrance-tunnels are cut across and obstructed by the coarse and closely packed frass of the later arrivals.

From the viewpoint of economic control there are resultant advantages if a tree is subject to attack by a complex of pests

rather than by one dominant species. Theoretically, a stable natural forest produces food-stuff in excess of its own requirements for maintenance and benefits if the surplus is consumed by other organisms.

Competition between individuals of the same species is often due to excessive egg-laying. It is the fault of the mother not of the child. Defoliators: Oviposition by the moths of a defoliator may be so extensive that all the foliage is eaten up by the time the caterpillars are half grown, whereas it would have sufficed to support a smaller number to maturity. Epidemics of defoliators are sometimes brought to a sudden end locally by the suicidal competition of starving caterpillars.

Borers: Competition between members of the same brood may be seen in the case of bark-beetles, particularly the polygamous species. Mother-galleries may be situated too close together in the bark so that there is not room enough for the development of all the larval tunnels arising from the egg-niches on either side of the mother-galleries. Those larvae that get the earliest start or obtain the most food survive at the expense of the lives of their weaker brethren. Here again it appears to be an error in instinct on the part of the parent but is in effect a simple means of ensuring the survival of the fittest.

3. BIOTIC CONTROL

i, Disease-producing organisms

Insect diseases of micro-organic origin are caused by fungi, bacteria, protozoa and viroses or imperfectly known agencies.

Fungous diseases: Among both the higher and lower fungi there are numerous forms known to cause diseases or blights.

A parasitic fungus may either live on the outer surface of the body of the insect without seriously damaging the underlying tissues; or it may penetrate the exoskeleton and destroy the internal tissues; it may send branching mycelia into the body filling up the tracheae and causing suffocation.

One group (Entomophthorales) is exclusively parasitic on insects (e.g., *Empusa grylli* on crickets, grasshoppers and caterpillars of *Taragama siva*, Lasiocampidae) and another group (Laboulbeniales) is almost exclusively parasitic on beetles, including aquatic forms. Scale insects (Coccidae) and white fly (Aleyrodidae) are particularly liable to destruction by entomogenous fungi. The Green Bug, *Coccus viridis*, is largely kept in check by *Cephalosporium lecanii*. Species of *Aspidiotus*, *Lepidosaphes* and *Mytilaspis* (Coccidae) are attacked by *Sphaerostilbe aurantiicola*. The larger fungi develop in the larvae and pupae of insects living in the soil [e.g., cockchafer grubs (Melolonthinae and Dynastinae attacked by *Metarrhizium anisopliae*), nymphs of Cicadidae, hibernating beetles and lepidopterous larvae] and

in wood-boring insects [e.g., the larvae of Hepialidae, Cossidae and Cerambycidae]. Green muscardine fungus is used for infecting traps for the control of the coconut beetle, *Oryctes rhinoceros*.

In the diseases produced by species of *Botrytis* and *Cordyceps* the mycelia of the fungus invade the body of the insect and its tissues are replaced by a secretion which partially mummifies it,—a condition termed muscardine. When adult insects are attacked, e.g., the larger moths of the Sphingidae and Noctuidae, the mummified body remains attached by means of the fungus to the leaf or bark on which it died. Often a large and prominent fructification arises on a stalk from the dead body in the soil or in wood tunnels. *Botrytis bassiana* is associated with the death of larvae of *Hoplocerambyx spinicornis* (Cerambycidae) during the hibernating period in the pupal chamber.

Bacterial diseases: The bacterial flora of insects is very rich. Diseases of bacterial origin occur in locusts (Acridiidae) and caterpillars and in larvae of honey-bees (foulbrood) and of *Hoplocerambyx*, accompanied in the latter by watery degeneration of the internal tissues.

Protozoan diseases: The parasitic Protozoa which bring about epidemic diseases in insects are species of Sporozoa, e.g., *Nosema* causing pebrine, which is a disease of silkworms and other Lepidoptera. The association of Protozoa with insects in many cases is not parasitic or harmful, e.g., in the intestine of termites, where they assist in the digestion of woody food, or in the stomach of mosquitoes where the alternate development of the human malarial parasite occurs.

Virus diseases: There is a class of infectious diseases of which the causative organisms are unknown but are presumed to be filterable or ultramicroscopic viruses. While the disease-producing organism is itself invisible it is frequently associated with visible foreign bodies of irregular shape termed polyhedral bodies. In a diseased insect these bodies occur in myriads together with fat-globules, urates, pigment-granules and broken down cellular tissue. The diseases are variously known as jaundice, wilt, grasserie or polyhedral disease.

Wilt diseases of the larvae of *Celosterna scabrator* (Cerambycidae) and caterpillars of *Hyblaea puera* are characterised by the complete disintegration of the tissues of the larva in which are found myriads of polyhedral bodies of various sizes. Silkworms suffer from jaundice or grasserie caused by a virus and accompanied by the formation of polyhedral bodies. The larvae of honey-bees are attacked by a disease known as sac-brood which is due to a filterable virus, unaccompanied by polyhedral bodies.

Disease of this type remains latent in defoliating insects and breaks out as the result of humid atmosphere or feeding on rain-soaked foliage, and is spread by feeding on contaminated foliage.

Economic importance: As natural control factors the diseases of insects are of considerable importance. An abnormal increase in the numbers of an insect pest is frequently followed by the appearance and rapid spread of a fungus or pathogenic micro-organism which destroys a high proportion of the numbers

of the insect, often exterminating it locally. At certain seasons wilt diseases are much more effective than parasites in controlling caterpillars defoliating forest trees. Such outbreaks appear to be dependent on the condition of susceptibility of the insect host and on favourable climatic factors (temperature and humidity). The practical utilisation of an insect disease by artificial culture and distribution during an epidemic of the pest has received much attention. Although some of the diseases are readily transmissible in the laboratory their artificial propagation in the field has rarely been successfully accomplished. If natural conditions are favourable epidemics of the disease occur naturally; if conditions are not favourable it appears to be impracticable to produce them by distributing the causative organism; but if the disease is not indigenous or has not automatically followed an introduced pest an attempt to establish it artificially is justified.

ii, Parasites and predators

Parasites and predators are carnivorous organisms that live at the expense of other organisms. In entomological usage there is not a definite line of division between the terms parasite and predator, although the distinction is of fundamental importance ecologically in connection with problems of numbers in an animal population.

A **parasite** is an organism that obtains its nourishment from its host in an indirect manner without killing its host beforehand and subsists upon one host-individual. A **predator** is an organism that obtains its food in a direct manner by killing and eating its host, or prey, and requiring a succession of victims throughout life. Between the two extremes, which are readily recognisable, there are carnivorous organisms that are not strictly the one or the other. Moreover many parasites are truly parasitic in the earliest stages of their existence and thereafter are predators. The main difference between the methods of a predator and a parasite is (as Elton explains) simply the difference between living upon capital and upon income: between the forest officer who cuts down a teak tree a hundred or two hundred years old, and the defoliator which levies its toll from generation to generation throughout the centuries: between the dacoit and the blackmailer. The general result is the same although the methods are different.

P a r a s i t i s m: A parasite must necessarily be smaller than its host. It may feed externally on the body of its host sucking the blood or body-fluids, an external parasite or **ectoparasite,** e.g., lice (Anoplura), fleas (Siphonaptera) and some species of Braconidae. In the majority of cases the parasite feeds inside the body, an internal parasite or **endoparasite,** living in the blood-space of the body-cavity absorbing the rich nutritive substances passed into the blood from the alimentary canal and stored up in the fat-

body. In the most perfect cases of parasitism it does not injure the host's vital tissues and may complete its development and leave the host without causing fatal injury. If death of the host occurs shortly after the departure of the parasite it is usually due to exhaustion or starvation, owing to the abstraction of the nutriment from it by the parasite, rather than to definite injuries in the vital organs. Perfect parasitism of this sort is achieved by Ichneumonoidea in the large bodies of gross feeders such as some Orthoptera, Noctuidae and Sphingidae. In the more usual cases of parasitism the insect is truly parasitic only in its earliest stages and completes its development in the last instars by feeding on the solid tissues of its host until only the empty dried-up skin is left. Under these conditions the method of nutrition changes, the structure of the body changes and the parasite becomes a predator. These are sometimes called **parasitoids.**

If an excessive number of individuals of a primary parasite occurs in one host so that the total is more than it can support and all die, the condition is termed **superparasitism.** When one host-individual is attacked by more than one species of parasite and the broods of each develop simultaneously, the condition is termed **multiple parasitism.** If a primary parasite is parasitised by another species, the secondary parasite is known as a **hyper-parasite.**

The principal groups of parasites are (a) the wasps of the groups Ichneumonoidea, Chalcidoidea, Serphoidea, Bethyloidea and Chrysidoidea, Scoliidae and Sphecidae, (see p. 464), the flies, Tachinidae, Calliphoridae, Phoridae, Bombyliidae, (p. 415) and the blister beetles, Meloidae. For biology see under family and species in Part One. And (b) Outside the Insecta the chief invertebrate parasites of insects are nematode worms (Mermithidae) which attack mainly nymphs and adults of Orthoptera, killing the individual or producing a form of parasitic castration and preventing reproduction. Caterpillars and some free-living beetle larvae are also subject to attack.

P r e d a t i s m : A predator is typically an active insect for it has to hunt for its prey and it must be swifter and stronger in order to catch and kill it. As a general rule a predator is larger than the animal on which it preys but some small predators combine to attack larger prey. An active life mean utilisation of energy in movement rather than in growth and consequently life is comparatively long. To support a long and active life a greater quantity of food is required than in the case of the short stationary and well nourished existence of an internal parasite, so that a predaceous insect must necessarily feed on a succession of victims of which often only a small portion of the body is devoured; generally the victims belong to a variety of different species. Some types of predators have quick life-cycles (Coccinellidae) and some are relatively sluggish (Syrphidae). On the whole predac-

eous insects are more varied in structure, habits and distribution than are parasitic insects, they occur in almost twice as many families as contain parasites and are probably richer in species.

The chief groups of predators are (a) the beetles, Carabidae, Cicindelidae, Coccinellidae, Cleridae, Elateridae, Staphylinoidea; the bugs, Pentatomidae, Reduviidae, Capsidae; the fossorial wasps; the robber-flies, (Asilidae), the Mantidae; the dragonflies (Odonata) and the Chrysopidae, Myrmeleonidae and Ascalaphidae, etc. For biology see under family and species in Part One. And (b) Outside the Insecta the chief invertebrate predators of insects are Myriapoda (centipedes), Arachnida, (spiders) and Acarina (mites).

The practical utilisation of parasites and predators for the control of forest insect pests is discussed in a later section, 5, Biological Control.

iii, Birds

Food-habits: A conventional classification of the food-habits of birds divides them into 3 groups, insectivorous, omnivorous and graminivorous. Insectivorous birds comprise those whose food consists almost entirely of insects in the nestling, young and adult ages. Omnivorous birds have a mixed diet of animal matter (including insects and other arthropods, worms, snails, small vertebrates, etc., as well as fruits, seeds, rotten vegetable matter) but none are literally omnivorous in the sense that they will eat anything and everything, and some are strictly carnivorous, disregarding vegetable matter. Graminivorous birds are those whose adult diet consists mainly or entirely of vegetable matter and whose earlier stages are nourised largely on insects. Very little has been done methodically to evaluate the economic status of birds in India and Burma beyond analysing the stomach-contents of adults. Such investigations fail to appraise the whole value or status of a species since they completely overlook the juvenile food-requirements. Moreover studies based on analysis of stomach-contents in different months of the year cannot really be appreciated without a knowledge of the density of the bird-population on areas of various types at successive seasons and no census of birds has been done anywhere in India (Salim Ali). Our ideas on their economic importance as agents in the control of insect pests of Indian forests are therefore little more than generalisations derived from the experience of other countries (chiefly Europe and North America). These indicate that insects are destroyed by the following types—tits, crow-tits, white-eyes, laughing thrushes, babblers, ioras, drongos, tree-creepers, warblers, minivets, fly-catchers, chats, redstarts, robins, swallows, wagtails, pittas, thrushes, Indian roller-bird, swifts, nightjars, woodpeckers, hoopoes, bee-eaters and cuckoos in the insectivorous group; pheasants, partridges, jungle fowl and quails among the mixed feeders; and grackles, weaver-birds, munias, finches, sparrows,

hornbills, barbets, paroquets, doves and grouse among the graminivorous birds which feed their nestlings on insects.

Quantity of food required by birds

Birds are creatures of intense metabolism, much more active on the whole than are other vertebrates, and require a large amount of food to keep them going. Each bird in the purely insectivorous group consumes a very large number of insects during the course of its life. Nestlings devour several times their own weight in insects daily and usually eat more than the parents eat. The food in the case of nestlings is utilised in supplying energy for extremely rapid growth; body-weight may increase at the rate of 20–60 percent per day. In order to supply sufficient food to a brood of nestlings the parent birds have to collect continuously from dawn till dusk visiting the nest several hundred times a day (e.g., starlings 170 visits, martins 300, wrens 600, hoopoes, 600). Birds digest their food very quickly and owing to the selective feeding digestion is singularly perfect, as may be concluded from the relatively small amount of faecal matter. The smallest birds require about 25–30 percent of their own bodyweight in dry food-substance daily; larger birds such as starlings require about 10 percent; a hawk requires only 5 percent. A small bird, e.g., a titmouse, will eat in the course of a day, 1,500 to 2,000 eggs of a moth, or 200 to 300 small caterpillars, or 100 pupae; a robin can eat in one day 70 cutworms together weighing more than the bird itself; a hoopoe can take 100 large insects a day; larger birds dispose of 200 grasshoppers, or 3,000 to 5,000 ants. A family of tits or nut-hatches (parents and 4 or 5 young) would require at least 25,000 caterpillars for a month's food (Mackenzie). A family of tits would in the course of a year destroy over 2 million caterpillars, if feeding only on caterpillars (Freiberger). The birds with a mixed diet vary the nature of their food considerably from season to season. At one time it may consist mainly of insects and at another time when insects are scarce it may consist almost wholly of seeds and fruits and vegetable matter.

Birds and forestry

It has been stated by enthusiastic-lovers that if all birds were destroyed agriculture would cease, forests would be threatened with destruction and man would be powerless to prevent it (Henderson, Salim Ali). They certainly stand supreme among vertebrates as enemies of insects. The data of economic ornithology are full of paradoxes but they have established the fact that, although the net benefit due to birds is enormous, it is of the same order as that due to other biological factors. Among foresters considerable divergence of opinion exists as to the role played by birds in preventing or bringing to an end epidemics of the major insect pests of forests. Opinions are most sharply divided perhaps in Germany where the encouragement and pro-

tection of birds in forested areas as a practical control measure was first conceived and where the idea has been most methodically tested. In India the important problem is the status of bird life in artificial forests, particularly in plantations. Provided the necessary shelter, nesting-facilities and water are present the richness of the insectivorous bird-fauna of a natural forest is determined by its insect-fauna, which is in turn determined by the floral composition of the forest. In a lesser degree this applies to the omnivorous avifauna also. Since birds are long-lived creatures compared with insects the numbers of the resident population of insectivorous birds are determined by the quantity and variety of food available when the food-supply is at its lowest level. Many insectivorous birds are selective feeders but the majority prey on whatever species of insects are most abundant and easily obtained. Some birds that are largely insectivorous are able to turn to a vegetable diet when insects are scarce. In a mixed forest with its diverse undergrowth insect-life is more evenly distributed throughout the year than in a pure forest with its restricted special insect-community which is abundant at one season and scarce at others. Hence the bird-population is more stable in an environment of many plant-associations and the insect-population is subject to a more uniform regulation. The regulatory force acts primarily in the prevention of epidemics, but it also takes part in the subjection of epidemics. Compared with the effect of parasites and other control factors it is probably relatively greater in the case of insects living in concealment (i.e., in the soil, under bark, or in wood) than in the case of the free-living insects.

Subjection of epidemics: The value of the resident avifauna in restricting oscillations and in preventing minor outbreaks is appreciable but is limited. When violent disturbances in the equilibrium are caused by climatic or other external factors the controlling effect due to birds is considerably depreciated. The reproductive power of birds is very small compared with that of insects and their rate of increase is therefore slower. The number of individuals of a species of bird in a given area is limited by other factors than the average food-supply from year to year. In certain classes of birds the area occupied by a species is split up into territories each of which is inhabited by a pair and particularly in the nesting-season intruders are at once driven out. When the food-supply increases rapidly in an epidemic outbreak of an insect it is impossible for the resident bird-population to increase proportionately rapidly and so profit by the temporary superabundance. The quantity of insects destroyed by them remains constant or at most increases somewhat during their breeding-season (which even in the tropics is rhythmic) while the percentage destroyed by them falls steadily, since it varies inversely with the density of the prey. For insects with several

generations a year the drop in percentage is greater than for insects with annual generations.

Though the resident bird-population is powerless to check *violent fluctuations in the incidence of an insect, considerable* assistance is afforded by nomadic and migratory birds. Outbreaks of defoliators are frequently followed by the arrival of large flocks of cuckoos, house crows, jungle crows, finches, kingcrows, jays, mynahs, starlings, thrushes, tits, etc., which settle temporarily in the forest and feed entirely on the pest; similarly a notable influx of woodpeckers accompanies an epidemic of borers; plagues of locusts attract crows, rosy pastor and mynahs. These concentrations are however temporary and do not ordinarily lead to a colonisation of the area, unless the epidemic is of long duration. They tend to damp fluctuations in the densities of the prey.

LITERATURE ON FOOD OF BIRDS:

Mason and Lefroy, 1912, *Mem. Dept. Agr. Ind., Ent.*, III, pp. 371, The food of birds in India.

D' Abreu, 1918, *Rec. Nagpur Mus.*, II, pp. 55, The food of birds in the Central Provinces.

Salim Ali, 1936, *Curr. Sci.*, p. 472-478, Economic ornithology in India.

Husain and Bhalla, 1937, *Journ. Bomb. Nat. Soc.*, XXXIX, pp. 831-842, Some birds of Lyallpur and their food.

iv, Other vertebrate predators

In the Amphibia adult frogs and toads feed extensively on land insects; a species of toad has been introduced into several countries for the control of scarabaeid grubs. The food-habits of small insectivorous Reptilia are almost completely unstudied. Lizards which frequent the soil-cover and foliage of trees are undoubtedly important predators of insects and many species of the smaller snakes are insectivorous, feeding particularly on grasshoppers and crickets. Among the Mammalia squirrels, mice and shrews eat insects inhabiting bark and twigs and the soil-cover and soil. Pangolins feed chiefly on ants and termites. Bats are primitively insectivorous and their food varies according to the species; some are selective feeders, e.g., on geometrid or sphingid moths only; others feed on a wider range of insects. Most of the prey is captured on the wing but visits to flowers and even to the ground are made by some species. The larger bats capture small birds, frogs and other bats. There is very little evidence to prove that they are destructive to mosquitoes which seem not to be taken selectively. The results of bat-roosts for the exploitation of their guano and for the local destruction of mosquitoes or fruit pests have been unduly exaggerated. Nearly all monkeys are largely insectivorous and will eat any kind of insect they can catch except certain universally distasteful or 'protected' types. The insect portion of their diet is greater than usually supposed yet they cannot be rated as having a great effect on insect epidemics.

ARTIFICIAL CONTROL

The chief fields of action in artificial control comprise cultural,

biological, chemical, mechanical and legislative control measures (see p. 797). A control measure may be indirect or direct in its action on the pest and it may be preventive or remedial in its effect. Its intention may be the production of environmental conditions that will ultimately restrict the abundance of the pest or it may be designed for the immediate reduction of damage in progress. Silvicultural and biological control are largely preventive but may also be used remedially. Mechanical and chemical control are largely remedial; although highly developed in agriculture these measures have a limited application in forestry.

It is impossible in practice to exterminate a forest insect pest. The object of artificial control is the regulation of the numbers of the pest to a level below which the damage done by it is financially unimportant. The damage may be represented by a financially measurable loss, but if this amount of loss is tolerable, i.e., is considered an inevitable accompaniment of the objects of management, the pest is said to be "under control" or economically controlled. An insect under economic control in this sense is by no means kept at a uniform abundance by the natural control factors; its numbers may fluctuate considerably below the level at which it becomes a pest of economic importance.

4. SILVICULTURAL CONTROL

By silvicultural control is understood the regulation of the abundance of a forest insect species by the factors of silvicultural practice. Silvicultural control is a form of artificial control because it results from changes in the natural controlling factors of the environment that are caused by the intervention of man. Silvicultural practice may be intentionally designed and employed so as to obtain the economic control of an insect pest, but more often than not it works independently of any intention on the part of the forest officer and is quite unappreciated by him.

Before discussing silvicultural principles from the aspect of insect pest control it is desirable to redraw a picture of the forest from an ecological view-point. The forest is more than a crop of trees with a certain density and rate of growth—it is also a community of organisms living together in intimate and intricate relationship, a life-community of which the stability and composition may vary very much. One of the most important variations that affects the insect-communities forming part of the biome of the forest is the gradation of environmental resistance in virgin and in other natural forests and in artificial forests.

Life-communities

In every different kind of habitat there is a life-community (biocoenosis) or society of organisms intimately dependent on each other and existing for a while in a more or less stable state of equilibrium. The basis of this life-community is the green plant,

which utilises the energy of the sun and the soil and produces food for the herbivorous animal, which in its turn feeds the carnivore. There is a complex system of food-chains forming what is called the biotic pyramid or pyramid of numbers. An essential component of the community is formed by the decay-producing organisms, (particularly the bacteria) that exploit the dead tissues of plants and animals thereby sustaining and speeding up the circulation of the food-substances. There is always a dominant vegetation type in any life-community on land—a plant-species or group of species that is most successful in the fight for sunlight. Each life-community comprises a vegetable hierarchy (Wells and Huxley). From small beginnings the community grows and develops, always tending in any one region towards the same stable climax.

If the climate permits the growth of forests then the dominants in the plant-community will be trees. In the tropics the normal climax that is reached by an orderly development of plant-communities is the rain-forest, permanently evergreen and composed of a great number of species of trees, climbers, shrubs and other vegetation intimately mixed. In the monsoon region, where the rainfall is heavy but definitely seasonal, many of the component species of trees are deciduous, shedding their leaves in the dry weather. In the zones of scantier rainfall the closed forest passes into open savannah-forest or into thorn-scrub. All such ecological types are the climax-stages determined by the climate and soil of the region in which they occur, and they remain stable so long as the general conditions of the environment remain unchanged. The plant-animal community of a climax-stage is termed a biome. One may consider the equatorial forest as the biome or climax-community of the planet as a whole towards which the life of all other regions is disposed to tend though checked in its approach by limitations of warmth, of water, or of soil (J. Huxley).

Virgin forest

The climax forest in its virgin state, unaffected by the intervention of man, is the outcome of long ages of competition and adjustment between all the elements of the forest-community, both plant and animal. It is composed of those species of trees which have survived the destructive forces of their particular environment but not necessarily of those which are best able to utilise the raw materials of the site. Its structure is by no means the best for economic production (Heske). One result of this competition between the plants able to grow in a particular environment and the animals which feed directly on them, is that any species of plant or any forest type which was unable to survive the attack of pests and diseases has been eliminated; and, as a reaction of the same process, those species of pests that destroyed their own host-plants have disappeared. The animal-

community of a climax forest is composed of species that in the long run benefit not hinder the growth of the trees. Insects have played a part as important as those played by other environmental factors in determining ecological trends and in hastening or retarding primary succession and retrogression of forests. In the finally balanced stage of the climax forest the species-composition of the community remains very much the same. The population-densities of these species are subject to rhythmic variations and often violent cycles of change, but these fluctuate about an average which, in a constant environment, remains constant. Animal communities may be treated as biological units which exist in a state of balance with their environment. Indeed, a static condition of this nature is essential for the existence of a long-lived organism like a tree which may survive for centuries. In one millenium, which is but five or ten rotations of a forest, there may be fifteen thousand generations of an insect feeding on it.

Freedom from insect epidemics: Since the abundance of these potential pests does not fluctuate abnormally, the trees in a virgin forest are not subject to destructive or fatal mass-attacks by the insects that feed on them. Diseases and insects, like the physical factors, cause a slow and continuous but replaceable wastage which does not develop into an epidemic. No biologist who has penetrated and explored a truly virgin forest in the tropics has ever reported the occurrence of insect epidemics or has seen evidence of extensive defoliation and borer-damage.

In tropical evergreen forests with their numerous species of trees and still more numerous hordes of insect-species the absence of epidemics is not surprising, nevertheless this feature is also characteristic of other forest types including the coniferous forests of the northern temperate zone. Abnormal local increases in the numbers of an insect-species may occur as the result of elemental accidents such as forest fires, windfall due to cyclones or hurricanes, floods, etc., but they are rapidly regulated. In virgin forests of the temperate region, and particularly in pure coniferous types, outbreaks of defoliators and bark beetles are known to occur, but these are believed to take place only in forest types that have passed their climax and are no longer the most suitable plant-formation for the locality. Their degeneration is followed by the establishment of a new and better adapted forest type. Insect outbreaks in such cases are due to a physiological disturbance of the equilibrium of the primitive life-community and are a normal autoregulatory factor.

Natural forest

Except in the deserts and arid region of the north-west and west and in the high Himalayas, the vegetation climax throughout India and Burma is forest, and a quarter of the combined area of these countries still carries forest; British India alone carries forest on about 20 percent of its area. Yet today there are very

few tracts of primeval forest surviving on the subcontinent to which the description "virgin" can be strictly applied. Most of the areas usually described in departmental literature as "natural forest" have at some time or other within the historical period been affected by the action of man. In places the disturbance dates back to prehistoric ages and has not been repeated, so that the lapse of time has allowed a return to an almost primeval type—the so-called secondary virgin forest or second growth forest; but over the greater part of the half million square miles of forest land in India and Burma the disturbance of the equilibrium has been severe or permanent. Numerous illustrations could be given of ancient fluctuation in the phytogeographic conditions of a region, the impermanence of the primeval forest and the ebb and flow in the succeeding secondary stages. Relatively modern history affords similar evidence where the forest encloses ruins of temples and stone buildings of considerable antiquity, or where the true climax forest is patched with seral communities that are developing on abandoned areas of early settlement and cultivation.

In such forests, which constitute the bulk of the reserved and protected areas in the charge of the Forest Departments of India and Burma, it is a fact that insect epidemics do occur. Their occurrence is no contradiction of the axiom of immunity of virgin forests. To the plant ecologist forests that are managed silviculturally or simply lumbered or even protected without exploitation, are not "natural forests" but are "semi-natural plant-communities". Natural forest is not synonymous with the virgin unaltered forest of nature and present day forest is not necessarily the true climax type.

Artificial forest

Forests of indigenous species formed by sowing or planting or induced seed-regeneration, whether as new afforestation or by conversion of existing natural forest, are by rigid definition artificial forests. Those types most nearly approaching the natural plant-community are forests managed under the selection system, or the continuous forest system (Dauerwald). These would be classed by some ecologists as artificial and by others as semi-natural. At the other extreme the most artificial type of forest is a pure plantation of a non-gregarious exotic species. All plantations at the beginning of the rotation represent an artificial environment, nevertheless subsequent management, or lack of management (as for instance in the case of small plantations "lost" or "abandoned" by the encroachment of the surrounding forest) may convert them into the equivalents of semi-natural plant-communities. Although the forester's main objective in regenerating a forest is the production of timber or fuel, at the same time he starts a whole series of processes normally culminating in the formation of a complex life-community.

ALL FORESTS ARE LIFE-COMMUNITIES

The foregoing discussion is intended to stress the idea that every type of forest, virgin or artificial, is a life-community—a complex of biological units—of which the health and even the existence depends on the uninterrupted and harmonious co-operations of all the organisms composing it. This mutual co-operation is most perfectly adjusted in the virgin forest and most disrupted in the extreme type of artificial forest. A complete understanding of the principles involved is essential before silvicultural methods can be elaborated so that they will prevent intolerable damage by insect pests while at the same time increasing the sustained yield to the highest possible point. It logically follows that the control of forest insect pests should begin concurrently with the preparation of the working-plan. Yet there are very few working-plans prepared in India that devote more than a line or two to the subject of insects.

Natural versus artificial forest.

The most important deduction from the experience of world forestry, and particularly of central European forestry, is that uniform even-aged forests, approaching the ideal form of the mathematically normal forest and established by artificial regeneration on clear-felled coupes, are most susceptible to natural dangers such as storm, fire, insect epidemic, deterioration of the factors of the locality, etc. It is equally well established that the closer the composition of a cultivated forest approaches a natural form the less is the recurrent damage due to insects. Although the respective merits of natural forest and of artificial forest have long been recognised, there still exists a long-standing controversy as to the economic conditions under which either is justifiable. The arguments for and against may be summarised as follows:—

On the one hand, it is contended that a rigorous system of sustained yield based on mathematical theories is the highest expression of the art of forestry; as in other technical operations man should dominate the natural processes; the increase in the financial returns more than compensates for the loss due to pests; extensive areas of one species of tree occur as natural formations in virgin forest; insect epidemics occur also in virgin or natural forests.

On the other hand, it is contended that only a forest in perfect health and subject to a treatment which conforms to natural laws is able to produce permanently the highest possible yield; forest management should in no way interfere with the natural laws of forest biology; natural control of insect pests reduces the costs of remedial measures to a minimum; depreciation of the factors of the locality is avoided; insect epidemics in virgin forest have occured only in the temperate zone and primarily in unstable pure coniferous formations.

(The entomological clauses in these arguments apply primarily to the danger from epidemics of caterpillar defoliators and bark beetles in coniferous forests of the north temperate region. In tropical and subtropical forests the diversity of types of insect damage is much greater but the same principles hold good for them).

Choice of the silvicultural system

To arrive at the decision on the advantages and disadvantages of a silvicultural system from the aspect of insect damage alone the forester must have at his disposal adequate evidence. He needs data for the calculation of crop yields, of financial losses caused by insects, of costs of remedies, etc., as well as reliable forecasts of variations in climate, market requirements and prices, and similar factors beyond his control. Such evidence can be based only on past experience of silviculture and management of the particular species of tree and of its known pests. The experience of other countries in analogous problems is helpful but not necessarilv applicable; for example, the coniferous bark-beetles of Europe and North America differ considerably from those of the Himalayas, in their destructive potentialities. In temperate regions epidemics of most types of insects are the culmination of *annual* cycles of increase; in the tropics epidemics flash out like forest fires and die away within the period of a season.

"The forester in his practice should make use of all known knowledge, should adapt his silvicultural system to meet the special requirements of the case with which he is confronted, and should refuse to be led astray by the craze of the moment". (Trevor). When such guiding principles are not available, as is often the case with the experimental forestry of untried trees in India and their little known insect pests, it is manifestly risky to create a type of forest that departs widely from a natural harmonious structure; the safest system to strive for is the selection system.

A pertinent warning is given by Heske in *German Forestry*:— "There is imminent danger of slipping into schematic forms of forest structure during the transition from virgin forests, or from forests subject to unrestricted exploitation, to forest under sustained-yield management. Virgin forests, especially in the tropics, contain innumerable trees of no present commercial value intermingled with a few that are highly valuable. It is only too easy to make the mistake of converting these mixed, uneven, virgin forests into uniform plantations of a single valuable species (Monokulturen). This mistake has been made repeatedly. Large areas have been afforested with even-aged plantations of a single species, chosen because it was fast-growing or especially valuable and without paying heed to the biologic factors that control the life of the forest. In spite of the initial success of these monocultures, the fundamental error of such practices has later become evident" (Heske).

Indian forestry provides several examples of monocultures that have either failed or suffered seriously from completely unsuspected pests, e.g.,

the babul borer in *Acacia arabica*, defoliators in *Dalbergia sissoo*, the Calopepla beetle in *Gmelina arborea*, the champ bug in *Michelia champaca*, the collar-borer in *Swietenia macrophylla*.

Silvicultural control, ideal and practical.

The ideal silviculture of pest control, therefore, is that which interferes least with the natural laws of forest biology. The chief outcome of the ecological viewpoint is the postulate of a general continuity in all silvicultural procedure. The conception that the forest is an organic whole, or biocoenosis, excludes *a priori* all abrupt changes. Silvicultural treatment should proceed in such a way that the forest would be unaware of it (Mœller). The slogan of Karl Gayer in the last quarter of the nineteeth century was "Back to Nature"; the doctrine of the Dauerwald or continuous forest as developed by Mœller is its successor and has become one of the principal foundations of modern forest management in Germany.

In India during the past quarter of a century there has been a very pronounced trend away from the selection system in favour of systems with concentrated regeneration either natural or artificial. The shelterwood system has been adopted for nearly all the pine and deodar forests and has been extended to most of the plains forests in modified forms. The great spread of clear-felling with artificial regeneration has affected teak-bearing forests most fundamentally but has been applied also to sal forests and mixed deciduous forest and is still under experiment for the regeneration of tropical evergreens. The last few years have seen a reaction from the unduly rigid application to all types of forest of the conversion to even-aged crops. The main trend of this reaction is in the direction of less rigid variations of the even-aged system and even (following the present fashion in Europe) back to a modernised selection system approximating closely to that of European practice (Champion).

In north America the relation of stand-composition to crop security was recently examined by a committee of foresters. The consensus of opinion was that the climax forest composition should always be used as a guide to a workable combination of species, but that, under present day conditiions, modifications are needed in certain cases in order to assure the fullest value of composition in its relation to crop-security. Present timber crops are not growing under the conditions which obtained in the virgin forests. The introduction of foreign insect pests and diseases is alone sufficient to make unsound any policy of rigidly copying the original forest composition. The first concern should be for the protection and security of the crop and the soil on which it is growing; the character and timing of intermediate and final fellings should be of secondary importance. Insect pests should be controlled not by expensive direct remedial measures but by developing resistant stands through silvicultural measures.

In India full consideration should be given to the relative

efficiency of irregular over regular systems of management making irregular working the aim in forests where conditions of regeneration render it feasible. Complete conversion, which entails large sacrifices of future revenue, should be avoided while the evidence needed for proper selection working is being obtained by experiment. Meanwhile the forest should be treated on its merits on 'safety-first' principles, using controlled selection fellings to improve the growing stock and natural or artificial regeneration to fill the understocked areas (Laurie).

Silvicultural control of insect pests thus presents a diversity of problems in Indian forest entomology. The existing problems are by no means clear-cut or stable, and new problems constantly arise out of the progressive development of Indian forestry. On the one hand are the investigations needed for artificially managed forests which are produced by conversion of uneconomic natural forests (virgin and ruined) or are created *ab initio*; on the other hand are the investigations arising from the reversion of uniform, evenaged, pure forests to more natural mixed types.

Modern ecological research confirms the general belief in the efficiency of nature's method of controlling insect pests, but it reveals that this efficiency is achieved by a multiplicity of converging processes many of which are latent until an emergency calls them into action. It is the task of the forest entomologist to isolate those processes that are essential and to evalute those that are supplementary for fully satisfactory forest management, *i.e.*, sustained yield, protection against insect attack, and maximum productivity. In the writer's opinion it is possible to ensure satisfactory natural control even when forestry cannot avoid breaking some natural laws, provided that certain essential laws are recognised and observed. The slogan "Back to Nature" should in practice be modified to "Back to the best in Nature".

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Regeneration areas

The general experience of classical systems of management is that the method of regeneration most closely approaching the natural process is the most immune from insect dangers. Artificial regeneration suffers more than natural regeneration. Where artificial regeneration follows clear-felling, damage by insects is greater than if regeneration is established under a shelterwood.

The clear-felled area: The most serious disturbance in the harmonious organisation of the life-communites constituting a forest occurs when an area is clear-felled. The operation destroys at the same time a whole complex of insect and small animal life and causes radical changes in important micro-ecological conditions such as light, temperature and moisture. In regeneration areas on which the unexploitable refuse is also burnt as in taungya, kumri, rab and other soil-preparation technique the destruction of life is far more extensive and its selective action under certain conditions favours injurious insects. (On the effect of fire see pages 837–839).

Repopulation of the devasted area by immigrant plant-eating insects is possible as soon as their food-supply becomes available, but repopulation of the same area by their natural enemies is a slower process and must always be subsequent to the establishment of the plant-eaters. The rate of repopulation by natural enemies and other desirable associated insects is influenced by the relative lengths of the life-cycle of enemy and host, the population-density of the host and its permanence and by the sequence of annual coupes. If the regenerated area is one of a series of contiguous annual coupes the colonisation of a coupe by natural enemies is a slower process than in a discontinuous felling-series in which each coupe is surrounded by much older crops. As a result of this lag in the reconstruction of pest-enemy communities, young crops in their first years are more liable to insect damage than in their later youth.

S i z e: A large clear-felled area is more dangerous than a small area (down to certain minimum limits). It is beneficial to distribute the area to be regenerated annually by means of small separate coupes (with an alternative choice of coupes) in several felling-series with frequent spatial variation of age-classes.

As an example of bark-borers may be taken *Ips longifolia* (Scolytidae) which attacks *Pinus excelsa*, *P. longifolia*, *Cedrus deodara* and other conifers. The broods which have developed in the debris and refuse of the felling-area emerge in the season following the felling and find no fresh felled timber available, they are forced to attack the living trees alongside the regeneration area. The possible concentration of attack in the marginal tree-growth is evidently greater from a large felling-area than a small one. From small coupes the beetles may disperse entirely to dying or dead trees in the neighbourhood and may not have to resort to living healthy trees at all.

P a t c h e s o r r a b s: Very small centres of artificial regeneration in the form of gaps or patches of a few square yards or chains extent surrounded by mixed forest are liable to severe

damage. The weeded patches are invaded from the surrounding cover by grasshoppers, crickets and cutworms which attack the seedlings or transplants above ground; and the soil fauna (cockchafer grubs, wireworms, mole-crickets, etc.) deprived of their normal food-supply attack the roots of the seedlings. The young saplings flushing in the light that does not penetrate the surrounding forest are very attractive to a host of polyphagous defoliators and sap suckers.

Patch sowings of *Cedrus deodara*, *Tectona grandis*, *Mesua ferrea*, dipterocarps, cardamon and many species tried in small plots in evergreen and rain forest are liable to damage of this nature.

Under the rab system in which artificial regeneration is restricted to a small percentage of the cleared coupe area the regenerated species, e.g., teak, occupies small islands surrounded by coppice or grass and its liability to severe damage depends very much on the composition of the miscellaneous vegetation forming the 'sea'.

Fire: The effect of fire can be considered from the aspect of burning and fire-protection.

Burning: The general effect of burning, (intentional or accidental), is to degrade the vegetation to a form typical of a drier climate than is indicated by the meteorological records, thus moist evergreen forest is degraded to deciduous forest or grassland, deciduous forest to savannah, and moist coniferous forest to scrub or grass. Where the general facies is not much altered, the species-composition is altered in favour of the fire-hardy species (Champion). The resulting type of forest is not stable and the life-community as a whole is not balanced; under such conditions abnormal damage by pests can occur.

The direct effect of burning on the forest fauna varies with the intensity of the fire. On regeneration areas burning may range from isolated bonfires, for the clearance of unexploitable refuse, to a conflagration that covers the whole area. This operation destroys a whole complex of insect and small animal life that cannot escape by flying or running. None of the forms living above ground or in the upper layers of the soil escape a fierce burn. The fiercest forest fires leave the area barren of fur, fin or feather. The pests are indeed destroyed but with them also all the beneficial and harmless members of the life-community.

The effect on the subterranean fauna inhabiting the deeper zones of the soil is different. Except in the case of the fiercest fires which calcine the upper layers of the mineral soil the fauna living at depths of a few inches from the surface is unharmed.

E.g., the larvae and pupae of *Dihammus cervinus* inhabiting the roots of *Clerodendron infortunatum*, and those of *Celosterna scabrator* in the roots of *Acacia arabica* or *Prosopis juliflora* are untouched by fires that destroy portions of the plant above ground, cicada-nymphs, termites, wireworms, cockchafer-grubs and their parasites, such as the asilid, *Promachus beesoni*, emerge successfully from burnt-over land.

In the case of soil insects feeding on roots in a regeneration

area the destruction of all alternative food-supplies by fire forces them to attack the roots of the new field-crop and concentrates the emerged beetles on to its foliage.

Wood-borers in green logs remain unharmed in a ground-fire owing to the low conductivity of the wood. Species like *Hoplocerambyx spinicornis*, platypodid shothole-borers, pinhole-borers, etc., complete their development successfully in logs the outer layers of which are charred.

Controlled burning in high forest destroys many of the free-living animals as is evidenced by the congregation of kites, hawks and other birds of prey on the lookout for corpses of mice, lizards, etc. Insects in the canopy or high up on the trunks drop into the flames; as was observed when ground-fires were used to destroy hoppers of the Desert Locust, *Schistocerca peregrina*, in sal forests and the champ bug, *Urostylis punctigera*, in plantations of *Michelia champaca*. Arboreal animals and birds, bats, etc. that can escape by flight may be prevented from returning by the destruction of the shelter that gave them resting and nesting facilities. Departmental burning which scorches or kills parts of the tree may start outbreaks of bark-boring insects.

E. g., controlled burning in young crops of *Pinus longifolia* kills the lower branches and *Pityogenes scitus* breeds in the killed and scorched bark; the emerging broods attack living undamaged saplings of *Pinus longifolia* and *P. excelsa* and with the assistance of species of *Polygraphus* and *Ips* such mass-attacks kill the trees. The effect of the destruction of the undergrowth in teak plantations was seen in Nilambur in March and April of one year when 2,600 acres out of 4,500 acres planted with teak were burnt. This was followed by "as complete a defoliation by caterpillars as I ever remember to have seen" (to quote a competent judge).

Under no ordinary circumstances is it wise to use a ground-fire as a remedial measure for an insect epidemic.

Fire-protection: The exclusion of fires from forests previously exposed to periodic burning has far reaching effects. Protection of grassland usually results in the development of tree growth, as for example, of *Macaranga* in the north Bengal sal tract. Protection in deciduous forests favours the fire-tender species, particularly evergreens, and results in the closing up of the forest with a greater variety of species and the addition of a proportion of evergreens varying with the climate and site and other factors. Fire-protection in most types of scrub growth results in their progression to tree forest, e.g., temperate montane scrub to *Pinus excelsa* (Champion).

The direct effect of continuous fire-protection on animal life is marked by the increase and permanence of animal populations and particularly of the natural enemies of insect pests. It assists in the stabilisation of the biotic balance in that it directly preserves the diversity of the fauna and indirectly adds to this diversity by increasing the richness of the flora. No cases are known in which the fire-protection of fire-degraded forest has increased the incidence of an insect pest although there is very

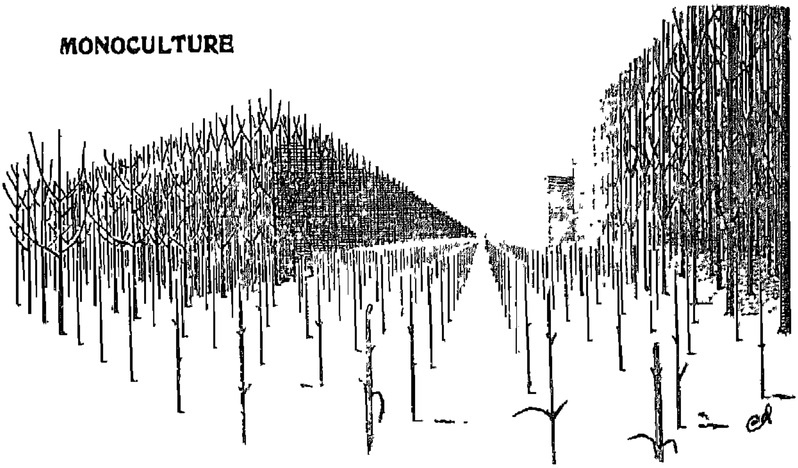


Fig. 197. Epidemic defoliation in a pure crop.

little reliable evidence either for or against. The beehole borer of teak, *Xyleutes ceramica* (Cossidae), may serve as an example. The general opinion of teak lessees in Burma is that beeholing has increased during the last 20 or 30 years under fire-protection, whereas ecological considerations suggest that fire is a factor favourable to the increase of the borer (Atkinson).

Pure crops

The monoculture [fig. 197], that is to say the extensive cultivation of a single species of an economic plant in a pure crop, is ecologically a very different thing from the pure stand of a naturally gregarious plant. The dominant species in the latter is either inherently free from diseases and pests and other natural dangers, or is protected from them by its plant-associates, viz., the soil-cover and undergrowth, which are integral parts of the plant-formation as a whole. The monoculture is dangerous because its intrinsic structure, its purity, provides the optimum environment for the multiplication of disease or pest organisms, the existence of which is initially determined by contributory factors. Nevertheless in the absence of contributory factors an artificial or unnatural pure crop may remain as free from damage by pests as a natural mixed plant-association.

Intrinsic structure: A pure even-aged stand formed of one species of tree and stocked at a density that excludes an underwood or a soil covering of herbaceous plants offers the most favourable conditions for the multiplication of the insect species that are pests of the tree because (a) the area carries the maximum and most concentrated food-supply; (b) the pest in all its active stages meets with the least difficulty in finding its food-supply or

breeding-material, and consequently the mortality in the potentially injurious stages, (i.e., the adults before pairing, the females before ovipositing, the larvae before beginning to feed) is reduced to the minimum; (c) the efficiency of control by parasites is less owing to the absence of parasites with alternative hosts; (d) the abundance of predators, both invertebrate and vertebrate, is less owing to the absence of alternative food for species that require a varied diet; in particular insectivorous birds are less numerous owing to the absence of nesting facilities.

Contributory factors: Among the contributory factors that influence the severity of economic damage in monocultures are; water-supply, soil, soil-cover, alternative food-plants, light, rate of growth, etc. Fuller details are given of each insect in Part One on its biology and in Part Two on its specific control measures.

Water-supply: A contributory cause of the epidemics of *Plecoptera reflexa*, p. 655, in the irrigated plantations of *Dalbergia sissoo* in the arid regions of the Punjab is delay in the initial and subsequent flushes of foliage, which in turn depend on the dates of irrigation and the depth of the watering. The subsoil water-table is too low to be tapped by the roots of young stands. In natural woods of the gregarious shisham the defoliator is rarely injurious since on such sites a high subsoil water-level or adequate winter rainfall allows the tree to come into leaf and mature its foliage early.

Flooding: Inundation of plantations of *Salix* by river-floods destroys the enemy-association frequenting the ground while the defoliator, *Lymantria obfuscata*, p. 639, is able to complete all stages of its life-cycle on the tree.

Soil: The result of forming monocultures of *Acacia arabica* irrespective of the capacity of the soil is uneven growth of the crop; the backward sites with unsuitable soil and deficient water-supply become permanent breeding-centres for the multiplication and spread of *Celosterna scabrator*, p. 153, and constitute the contributory factor to its high incidence.

Soil-cover: i, *Ectropis deodarae*, p. 598, is rarely responsible for defoliation of economic importance in pure forests of *Cedrus deodara* over most of its range. But in the outer Himalayas it is epidemic for several years in succession in forests that are subject to heavy grazing and litter-removal. The trampling and exposure of the soil affects pupation and the disappearance of the proper flora reduces control by natural enemies. ii, The incidence of complete stripping of teak is highest in plantations devoid of undergrowth or soil-cover. It is very severe in any type of teak crop subject to frequent ground-fires and in such peculiar types as *malki* forests in Bombay where teak is a reserved tree and every other kind of vegetation and litter may be removed by right-holders.

Alternative food-plants: i, The incidence of attack by *Pagiophloeus longiclavis*, p. 285, in plantations of *Swietenia macrophylla* is primarily determined by the extent of breeding in *Cedrela toona* in adjoining forests. This is also a case of an exotic adopted as food-plant by an indigenous insect. ii, The incidence of the teak canker-grub, *Dihammus cervinus*, p. 163, is similarly determined by the extent of breeding in *Clerodendron infortunatum*. iii, The invasion of plantations of *Michelia champaca* by *Urostylis punctigera* starts from other species of Magnoliaceae in adjoining mixed forest. iv, Climbers in which longicorn or chrysomelid borers breed may be a source of injury to the trees encircled by the climbers, e.g., *Apriona swainsoni*, p. 144, and *Butea superba*, or *Sagra longicollis*, p. 230, and *Thunbergia grandiflora*.

Light and shade: The population-density of *Hypsipyla robusta*, p. 686, in the tropics and subtropics is primarily determined by the quantity and rate of production of leading and lateral shoots of its food-plant. In pure plantations of mahoganies or cedars in the open, shoot production and borer-damage are at the maximum; under the shade of overhead canopy or with the lateral protection of intermixed plants or jungle-regrowth the incidence of attack is less.

Rate of growth: The local incidence of *Xyleutes ceramica*, p. 577, is affected primarily by the amount of normal annual rainfall; the beehole-incidence of the individual teak tree is determined by its age and volume. In an even-aged stand it is proportional to volume but timber-increment can be made to outstrip borer-increment.

Mixed crops

From the aspect of insect damage some redefinition of familiar terms is desirable. To the forester a mixed crop of trees is one in which there are two or more valuable exploitable timber species; from the viewpoint of insect control it is an association of several species of plants in which units of the subsidiary flora gain importance in proportion to their effect on the population-density of the insect pests of the timber crop. To the forester a natural mixed forest consists of exploitable species and miscellaneous or worthless species of trees and the rest of the subsidiary flora is disregarded; to the ecologist the important point is whether the forest is a climax (or subclimax) type or is in a degenerate transition phase: its composition must be expressed in terms of desirable, neutral and undesirable elements of the pest's environmental resistance. Obviously the unqualified term 'mixed crop' means very little in insect control: there are good mixtures and bad mixtures and a 'natural' mixture is not necessarily the best

The chief characteristic of a mixed stand is the specificity of

its pests; it may be a mixture of species of trees (a) each of which is attacked by the same species of pests, i.e., the pests are oligophagous or polyphagous, or (b) none of which have pest species in common, i.e., the pests are monophagous, at any rate in the particular mixture.

(a) **Polyphagous pests:** The phytophagous insect fauna of a mixed forest usually contains many species capable of feeding on more than one species of plant in the community. Those feeding on the living tree are usually not regular pests of economic importance and do not become epidemic until after the occurrence of an abnormal or temporary disturbance in the environment, e g., outbreaks of lymantrid defoliators in sal forest or of chafer and weevil defoliators in mixed deciduous forests. The polyphagous borers feeding on the felled tree, on the contrary, readily become major pests as soon as any item in their food-supply is produced in quantity by improvement fellings, thinnings, girdling of overwood, etc., that are not followed by extraction or disposal of felled material. In artificial crops species susceptible to the same pests are sometimes associated in intimate mixture or in adjacent plantations, e.g., *Tectona grandis* and *Gmelina arborea*, or *Cedrela toona*, *Chikrassia tabularis* and *Swietenia macrophylla*, or *Acrocarpus fraxinifolia*, *Cassia fistula* and *Cassia siamea*. Such combinations are equivalent to pure crops.

(b) **Monophagous pests:** Mixtures in which each species has its own series of insect-pests, are more usual. The value of a mixture in protecting the principal timber-species in the crop lies in the following advantages, (a) reduction in the quantity of food available to the pest on the area, (b) improvement in the environmental condition of parasites and predators of the primary pests; congenial shelter and a more varied food-supply are available for predators which can exist on other prey when the primary pests are not abundant; insectivorous birds find a more assured supply of food throughout the year and facilities for nesting and rearing their broods; the adults of parasitic flies and wasps are benefited by the occurrence of herbaceous vegetation and flowering annuals, (c) the parasite population may be maintained at a higher level owing to the existence of alternative hosts, (d) mechanical obstruction is offered to the dispersal of crawling and flying defoliators, etc.

Composition of artificial mixtures: There are two types of spatial arrangement of the constituent species in a mixed stand, (a) the underwood or soil-protection storey forming with the main crop, a vertical mixture, and (b) the crown-mixture or horizontal mixture.

(a) The mechanical effect of a vertical mixture, main crop and underwood, is negligible in restricting the movement of flying insects and eventual oviposition on their food-plants; but it is

beneficial in checking the spread of crawling insects such as caterpillars and nymphs, particularly those that habitually drop to the ground from the crowns and reascend the trees. If the number of stems in the underwood is greater than the number in the main crop the majority of the caterpillars climb up into the foliage of the under or middle storeys, where they either starve or (if polyphagous) continue their feeding on the undergrowth. Although the underwood may be stripped the defoliation of the more valuable crop is proportionately reduced to an extent that may be the difference between severe and tolerable defoliation. An underwood is of value in providing nesting facilities for insectivorous birds, and shelter for other predators, e.g., lizards, spiders. If composed of the right species the underwood may be very valuable as a source of parasites; this aspect is fully discussed under Biological Control.

(b) A horizontal mixture in the overwood by individual trees, or by alternate lines of different species offers little obstruction to defoliators or borers or other pests of the living tree. Mixture by s t r i p s or blocks at widths of 50 to 100 feet does not prevent the interchange of flying insects between neighbouring strips, except sluggish or fragile windborne forms, and consequently does not restrict egg-laying. It has an appreciable effect in limiting the spread of caterpillars and other larval stages that feed on the foliage. Some advantage can be obtained by the use of strips in the case of defoliators that are in the habit of spreading from crown to crown, or dropping to the ground and ascending other trees. Mixture by b l o c k s or groups of large extent reproduces the conditions of pure forest on a small scale. The risk of damage within each block is not eliminated although proportionately reduced; the risk of spread on an epidemic scale is less from disconnected blocks than from extensive continuous areas. But provided the factors of the locality are taken into account and the extent of a block or group is determined by soil-conditions and the most suitable species is used for the particular patch of ground, one can create a mixture of blocks that will be less liable to damage by insects than a mixture arranged by lines or narrow strips. However, the great difficulties in managing a large area of forest cut up into small pure groups may offset the advantages obtainable from this method.

When epidemics of defoliators or of borers develop on a catastrophic scale no type of forest composition, mixed or otherwise, will be effective in preventing attack.

In the widespread migrations of *Hyblaea puera* and *Hapalia machaeralis*, which follow on severe epidemics of these defoliators, every teak tree scattered throughout square miles of natural teak-bearing forest is discovered and stripped. And in wholesale epidemic outbreaks of *Hoplocerambyx spinicornis*, isolated sal trees in the open country or in miscellaneous forest do not escape attack.

Hence, the general conclusion is that dilution of a pure crop

by mixing one or more less valuable species in the crown canopy, whether by intimate individual mixture, or by lines or strips, or by small blocks is not likely to achieve a reduction in insect damage commensurate with the reduction in the value of the crop as a whole. Either the valuable species should be grown pure or it should not be grown at all and a crop of a less valuable species will probably pay better. The controlling effect of an underwood or of underplanting depends on its ability to maintain a reserve of parasites of the pest and presents a problem that cannot be expressed in general terms but must be solved for the particular species of tree and its particular pests.

Thinnings

The postulate of a general continuity of silvicultural procedure as ensuring the maximum protection against the insect hazard applies to thinnings. Thinnings that take place at intervals of as short as 5 to 10 years must necessarily be proportionately heavy and in consequence the transition from one state of density of the crop to another is abrupt. In nature change in the spacing of trees is a continuous process. Hence the ideal thinning procedure is annual with no separation between intermediate and final fellings; thinnings proceed slowly without interruption to regeneration fellings.

Hygiene: Thinnings at all times should remove (i), recently dead and not yet dry trees in which bark and wood-borers normally breed, (ii), dying trees in which borer-attack is partially established or will soon commence, (iii), weak or unhealthy trees, since these are more susceptible to attack by defoliators or sap-suckers owing to difference in the time of coming into leaf or to weaker physiological resistance.

The removal of dry trees, that have been dead 2 or 3 years and more is not of any value as a preventive measure. On the contrary the fuana of dry or partially rotted trees comprises on the whole beneficial animals which may with advantage be preserved. The retention of large *Ficus*, and other trees useful for shade, camping-grounds, elephant-fodder, etc., is a protective measure, as these shelter useful animals and do not breed any species injurious to the principal timber-trees.

Early thinnings can be used to reduce the numbers of borers that attack the living seedling or sapling; later thinnings cannot be used for this purpose, as either the attack cannot be easily detected (beehole borer) or does not take place on older trees (*Dihammus*, *Phassus*).

Density: The degree of density of the crop influences the physical conditions by modifying the intensity of light, evaporation, air-movement and fluctuation in temperature, all of which indirectly affect insect-life.

i, Recovery after attack by shoot-borers, e.g., *Hypsipyla*

robusta, p. 686, *Tonica niviferana*, p. 662, *Zeuzera coffeae* p. 581, is affected by density; in a fully stocked stand the straight growth of substitute leaders is stimulated and the partial shade reduces liability to further attack. ii, Excessive density may be harmful with some pests, e.g., young regeneration of *Dalbergia sissoo* produced by thick line sowings multiplies defoliators more than that produced by widespread cuttings (stump transplants). iii, Epicormics may be due to congestion of the crop so that the crown buds do not respond to thinnings; they are also due to destruction of crown buds and foliage by defoliators. With teak and some other species a cycle may be started in which epicormics increase defoliation and defoliation increases epicormics. iv, In an even-aged teak plantation the beehole-incidence of trees of the smaller girth-classes is higher in proportion to volume of timber than in the dominant and high-girth-classes; thinnings can regulate the periodic mean annual increment so as to reduce the beehole-volume incidence (p. 577).

5. BIOLOGICAL CONTROL

In modern usage BIOLOGICAL CONTROL means the employment of the natural enemies and diseases of a pest for the purpose of maintaining economic control. It is not limited to the utilisation of parasites only, as popularly supposed, but is concerned with *all* natural enemies and diseases. In forestry it is used in conjuction with silvicultural control and may be regarded as an extension of the same. A further development of biological control is the destruction of noxious weeds by means of their insect pests.

Amidst the multiplicity of theories and experiments evoked by this new art, forestry is concerned mainly with the principles of three biological methods, viz:—i, Mass-production and release of selected parasites or predators as a regular annual operation, ii, Importation and colonisation of species that are not indigenous —a non-recurrent operation, and iii, Improvement in the environmental resistance of the pest by modification of the plant-community so that control will work automatically —a part of the cultural operations. Common to all three are the principles applied in selecting the species of enemies most suitable for the operations.

The relative value of parasites and predators

The merits of parasitism versus predatism and of monophagous versus polyphagous species offer problems on which divergent views are held and various mathematical-biological theories are propounded. An early and simple generalisation placed the order of efficiency as 1, specific parasite, 2, polyphagous parasite, 3, specific predator and 4, polyphagous predator. It is now evident that the qualities desirable in an enemy vary greatly with the characteristics of each pest and its environment.

D e s i r a b l e q u a l i t i e s : Among the more important are:— *i*, Ability to outnumber the host which depends upon fecundity, sex-ratio, length of life-cycle and ability to find the host. *ii*, Specificity. The merits of a monophagous versus a polyphagous parasite or predator depend on the characteristics of the host. E.g., for a gregarious host breeding steadily throughout the year in the tropics a strictly monophagous species is desirable; for a pest whose density fluctuates widely and periodically a monophagous species must be very closely adapted if it is to be more efficient than a polyphagous species. *iii*, Competition in the form of multiple parasitism or hyperparasitism reduces the effectiveness of a parasite; just as parasitism is a factor regulating the abundance of the pest so hyperparasitism regulates the abundance of parasites. Competition between predators and parasites is modified by the fact that an individual predator destroys many pests (and parasitised pests) during its life whereas each parasite destroys only one pest and several parasites may develop in a single host. *iv*, The response of an enemy to the physical environment decides if it can survive under a new set of conditions. *v*, Dispersal. An enemy that can disperse as rapidly and widely as its host is essential for a pest with a short life-cycle and variable abundance.

Between parasites and predators as a class there is not any striking difference in the effective rates of reproduction or in their specificity. The most important difference is that, while the number of offspring produced by a parasite is proportional to the number of hosts found, there is no simple relation between the number of prey found by a predator and the number of its offspring. Polyphagous parasites can control their hosts at higher densities than specific parasites can. In contrast the densities of polyphagous predators are less dependent on variations in the density of any one of the species constituting their prey. It is an interesting paradox that although predators are destroyed by other primary predators or by their own kind this destruction actually permits more predators to survive when prey is scarce than would otherwise be possible. (see also Biotic Control p. 822).

Obviously in order to make a successful choice of species of enemies for introduction to a new locality many unknown factors ought to be accurately worked out beforehand and deductions made as to what will result from an introduction. This ideal can rarely be attained without laborious and complex research; in a practical project it is usual and simpler to introduce a likely species experimentally and observe the immediate results as a basis for extension.

i, Annual mass-production of natural enemies

P a r a s i t e s : In India a certain amount of experimenting has been done on the artificial multiplication of parasites in labora-

tories with the object of releasing them in instalments during the period the pest is active each year. So far the work has not advanced much beyond the technique of mass-production; the cost of producing say a lakh of parasites as a commercial proposition and their effect in terms of increased crop yield are still unstandardised factors. The world-famous egg-parasite, *Trichogramma evanescens*, p. 518, is an exception and substantial increases are claimed in the yield of sugarcane of treated fields in Mysore (Subramaniam, 1940, *Proc. Third Meet. Crops and Soils*, pp. 204, 205) Other species used on these lines are *Microbracon brevicornis* for the pink bollworm of cotton, *Microbracon greeni* and *M. hebetor*, pp. 482-483, for the lac predators (see later on control of *Laccifer lacca*). The use of this method is essentially limited to agriculture and fruit-culture, i.e., to crops giving an annual yield. In forestry it is doubtful if the maintenance of parasite laboratories for the regular production and liberation of parasites or predators in valuable plantations can be organised as a practical profitable control measure but the possibilities of the method are being investigated in Burma (see later, control of *Xyleutes ceramica*).

ii, Importation and colonisation of foreign species

The principles underlying this form of control are (a) that the natural-enemy-complex of an indigenous pest is incomplete in a particular locality owing to the absence of certain efficient species of its parasites or predators, and (b) it is advantageous to strengthen the enemy-complex by importing or restoring the missing elements.

(a) These missing species may be absent from the locality for various reasons, e.g., i, zoogeographical: the original natural distribution of a widespread pest is not uniform with that of all its parasites and predators; or ii, cultural: the food-plant of the pest has been extended artificially beyond its natural range and some elements of the enemy-complex have not passed barriers surmounted by the pests; or iii, catastrophic: the environment of the food-plant has deteriorated and become unfavourable to some indigenous species of enemies which have died out temporarily. Thus the missing species may be truly foreign in that they are natives of other regions, or may be potentially indigenous in that accidents have prevented their inhabiting or exterminated them in the locality under consideration.

(b) The basic assumption that a deficient enemy-complex is improved by the addition of extra elements is not universally accepted; counter-arguments contend that a pre-existing balance is upset, the effect of competition is unpredictable, one cannot improve on "nature", and so on. It is at any rate probable that deficient control due to reasons i-iii above can be improved in artificial and semi-natural forests. By extension of the principle

a further means of strengthening the enemy-complex of a pest is admissible; it is possible to make use of species of parasites or predators known to attack very close allies of the pest and proved by experiment to be capable of adopting the new host.

In practice the desired controlling species is imported and multiplied and liberated in the new locality in colonies large enough to perpetuate themselves after the initial establishment which may be achieved in one or a few successive years. Surveys are made after a suitable lapse of time to ascertain if the species has survived; the technique of the silvicultural sample plot is required to evaluate the controlling effect.

Introductions on these lines have been made with teak defoliator parasites, e.g., *Apanteles malevolus*, p. 473, *Cedria paradoxa*, p. 477, *Dioctes gardneri*, p. 508, in South India and Burma; shisham defoliator parasites and predators, e.g., *Anthia sexguttata*, p, 121, *Deiphobe incisa*, p. 726, *Disophrys sissoo*, p. 479, *Microgaster plecopterae*, p. 484, in the Punjab; coconut-caterpillar parasites, e.g., *Trichospilus pupivora*, p, 479, in Ceylon and South India; fluted scale predators, e g., *Rodolia cardinalis*, p. 245, on *Acacias* in the Nilgiris.

iii, Increase in environmental resistance

Measures designed to increase the environmental resistance of a pest, i.e., to intensify the action of all its natural control factors so that it is maintained permanently in a state of economic control, can be used when the crop is grown on a long rotation as in forestry; they are rarely applicable to the annual crops of agriculture in which the environment is largely destroyed at each harvest or fallow period. The system as developed for forest entomology in India applies new principles; at any rate, known principles do not appear to have been combined and elaborated on the same lines by forest entomologists in other parts of the world.

Natural control of insect pests is not working at its best in many so-called natural forests in India, because, in actual fact, these forests are far from natural. They have been profoundly altered in the past by unregulated exploitation of timber, by grazing, by fire or by the exercise of other human activities Under protection and conservation a miscellaneous flora has appeared and grown up constituting with the timber trees a mixed forest that rarely provides the strongest environmental resistance to the pests of the timber species. By similar fortuitous reactions, but in a more restricted fashion, the soil-flora and undergrowth of plantations has come into being. The natural colonisation of an area by the commonest and hardiest plants which arrive first on the scene does not produce the biocoenosis most favourable for the objects of management; nature introduces many species of plants that are absolutely neutral for the control of the major pests. Research in India has therefore analysed the environmental resistance of the chief pests of forests with the academic object of discovering the essential factors for optimum natural

control and the practical object of deciding which of those factors can be reproduced by silvicultural methods.

Desirable and undesirable plants: The plants of a conserved *forest or plantation can be classified in 5 categories according to* their value in biological control.

i, The plant supports insects that are alternative hosts of the parasites and diseases of the pests of the main crop. It is a desirable element in the forest because it provides hosts for these enemies of the pest at times when the pest itself is scarce. Thereby a reserve force of polyphagous (or oligophagous) parasites is maintained ready to attack the pest when it reappears in numbers.

ii, The plant supports insects that are part of the varied diet of polyphagous predators that also feed on the pests. Predators are relatively long-lived compared with most parasites and pests in subtropical and tropical forests and are more adaptable to alternative sources of food. Plants classed in category i. also comply with the definition of category ii. and in this double role are more valuable in biological control than plants supporting predators only.

iii, The plant provides suitable shelter, nesting and breeding facilities for the vertebrate and arthropod predators, e.g., spiders, birds, lizards, etc.

iv, The plant is an alternative food-plant of a pest feeding on the trees of the main crop. It is undesirable in a mixed forest or near a plantation because it permits a multivoltine pest to continue breeding during the season when its chief food-plant is leafless or when its foliage is unpalatable or its shoots are mature. This extended period of breeding results in the initial population of the pest, at the time its chief food-plant renews vegetative activity, being higher than it would be were no alternative food-supply available. This disadvantage outweighs any benefit that may be supposed to arise from the plant's ability to attract part of the pest-population away from the main crop. Such species should be eliminated.

v, The plant is quite neutral by all tests of biological control; it is undesirable when it occupies space that could be put to better purpose.

The synthetic forest: Given exact data of this kind on the plant-associates of a timber species and its pests, one can formulate a mixture which will afford the maximum protection to the timber crop in any climate or on any soil, i.e., one can define a synthetic forest. It can be attained by encouraging or introducing the desirable plants and by eliminating the undesirable or neutral plants, using selective weeding and thinning and underplanting as the practical means. The synthesis can be a gradual process and the protective effect will be proportional to the effort expended successfully and to the progress made towards the ideal. It is not a hit or miss remedy.

Category i. comprises the most desirable species; these should be protected at the expense of all other elements in the natural undergrowth or jungle regrowth and, if they are numerous enough to stock the whole area, groups ii. and iii. need not be considered (see measures for the control of teak defoliators). Species of group ii. are important when those of group i. are relatively few and carry a poor or definitely seasonal fauna of defoliators, etc. Species of group iii. are always desirable along the boundaries of regeneration areas and along drainage lines or small permanent streams intersecting the area; they should be preserved by excluding narrow strips of natural vegetation along such lines from the coupe to be clear-felled or thinned and should be protected from fires. Species of group iv. should be eliminated everywhere. (See the biological control scheme for teak defoliators under *Hyblaea puera*).

Beeson, 1934, *Ind. For.*, pp. 672-683, The biological control of teak defoliators — 1938, *lit. cit.*, pp. 485-492, Undergrowth and the biological control of teak defoliators — 1941, in *For. Bull.* on The pure teak plantation (revised edition).

Encouragement and protection of insectivorous birds

In localities where the bird-fauna is impoverished and scanty it is desirable to attempt the colonisation of some part of it artificially. Extensive plantations of one or few species of trees, continuous areas of successive age-classes, felled areas and forest nurseries are the types of stands most in need of bird-protection.

Bird sanctuaries: What wild birds need is food and water, a suitable habit, attractive nesting-places, and protection from foes (Taylor). Facilities for nesting and shelter can be provided by reserving or introducing artificially trees suitable to form shrubby undergrowth in patches and at suitable times pollarding it so as to induce thick branchy growth; such bird-sanctuaries should, of course, be located near permanent water, i.e., a stream, pond or water-hole. Reservation or planting of berry- and fruit-bearing trees results in the attraction of some kinds of omnivorous birds that also feed on insects. If dry trees are left in an area there is a likelihood of their being used by woodpeckers and by birds that nest in abandoned woodpecker-holes. Trees of worthless miscellaneous species and trees to be removed over advance growth may with advantage be girdled and left for this purpose.

Nesting-boxes: In special cases nesting-boxes may be provided with the object of attracting birds to breed in the desired place, and of affording safe roosting-places and refuges at other seasons. A great variety of nesting-boxes has been designed of different sizes and shapes to suit the requirements of various species of birds. For details reference should be made to publications on bird-protection, e.g., Berlepsch H. V., *Der Gesamte Vogelschutz*; Kalmbach E. R., *Homes for Birds*, Farmers' Bulletin, 1456, (1925): Thompson C. W. St. C., "*The Protection of*

Woodlands," (1928). Various precautions have to be observed as to the location and method of hanging nest-boxes, and the accessibility of a permanent water-supply. It is estimated that 4 nest-boxes per hectare are required for effective protection in Germany. The effective range of a pair of insectivorous birds at breeding time is about 50 yards from the nest. An area of 1,000 acres would cost Rs 2,000-2,500 initial outlay (1,600 nest-boxes) and Rs. 150 annual upkeep. Mackenzie (*Ind. For.*, 1921, p. 317) estimates for 1,000 acres of teak plantation Rs. 200 (100 nest-boxes) and Rs. 4 annual upkeep. Arrangement for artificial water-supplies and feeding during times of need that form part of a bird-protection scheme in other countries might possibly be considered in India, e.g., in casuarina plantations.

Protection of gamebirds: Those sections of a forest in which the protection of insectivorous birds is organised should be entirely closed to the shooting of gamebirds. (See also pp. 824—827).

"The problem of effective, cheap and permanent control to counteract the bad effect of intensive silviculture is seen to have been solved by the proper encouragement of certain insectivorous birds. *It is entirely a* matter of opinion or of prejudice as to whether or not this policy is adopted by the management. The small initial outlay for nesting-boxes has always shown itself to be a very good investment indeed." (G. W. St. Clair Thompson).

Biological control of weeds

Lantana aculeata

The first attempt to control a noxious foreign weed by importing its insect enemies from its country of origin was made against lantana in the Hawaiian Islands. *Lantana aculeata* (*camara*) is indigenous in tropical America. It was introduced into India about 1809 and planted in the Calcutta Botanical Garden; it was introduced to Ceylon about 1826, probably from India, and had become a weed ten years later (1839). About 1860 it was *established in the Hawaiian Islands where it increased* and became a serious pest in the pastures of low-lying regions, its rapid spread being assisted by the Chinese turtle dove and the Indian mynah, which birds had also been introduced to the Islands.

Hawaiian Is.: In 1902 the Hawaiian Board of Agriculture and Forestry sent an entomologist, A. Koebele, to Mexico to secure any promising insect enemies of lantana for introduction to the Islands. Koebele found something like 400 species of insects associated with lantana in Mexico out of which he selected a large number as likely to be effective controlling agents and at the same time safe as regards other vegetation. The story of the search for and discovery of suitable species and the difficulties encountered in exporting the material is of unusual interest. It has been frequently written up, but that by R. C. L. Perkins

and O. H. Swezey (1924, Bulletin No. 16, Expt. Sta. Hawaiian Sugar Planters Assoc.) is the most authentic account of the details. The numerous consignments sent had several days' journey through hot country to San Francisco whence they were shipped in cold storage to Honolulu. Much that was not desiccated was destroyed by mould but eventually, of the 23 species of insects exported, 8 reached Honolulu alive and were successfully established by Perkins. These are a tortricid moth, *Crocidosema lantana*, and a plume moth, *Platyptilia pusillidactyla*, p. 694, the larvae of which destroy the flowers; a seedfly, *Ophiomyia lantanae*, p. 416, which bores in the ripening berries; a tingitid bug, *Teleonemia scrupulosa*, p. 785, which sucks the young leaves and shoots; a gall-fly, *Eutreta xanthochaeta*, which galls and checks the new shoots; a tineid leaf-miner, *Cremastobombycina lantanella;* and two butterflies, *Thecla echion* and *T. bazochii*, the larvae of which feed on the flowers.

By 1905 the introduced insects had become generally distributed through most of the island and none of the Mexican species has become injurious to any cultivated plant in Hawaii. The Hawaiian entomologists are generally satisfied with the results of the introduction of these Mexican insects and consider that their combined attack has greatly checked the production of seed and has reduced the vigour of the plant. It is not claimed that lantana has been exterminated in Hawaii, but that the area occupied by it at the present time is a great deal less than formerly. The insects have proved most effective in the drier regions. Swezey stated in 1924 that where the land is cleared of lantana for grazing or agriculture it is not usually re-occupied by lantana; instead, other noxious shrubs and trees appear, some of them much more difficult to eradicate than is lantana. Amongst these weeds are guava, *Acacia farnesiana* and *Leucaena glauca*. A. D. Imms, who visited Hawaii in 1925, considered the control of lantana as having been partially accomplished by the introductions and that the colonisation of other insects should be attempted. K. Kunhikannan, Government Entomologist, Mysore, formed a somewhat different opinion as a result of a visit in 1921. American capital and enterprise have wrought a transformation in the course of a generation embracing every aspect of civilized advancement. Enormous areas have been brought under scientific cultivation. Plants and animals have been introduced, propagated and spread and the population has multiplied rapidly. These are the forces, according to Kunhikannan, before which lantana, must inevitably have receded and the further setback it has received from insect pests should be looked upon as no more than supplementary.

Fiji, Australia: The results achieved in Hawaii have been thought sufficient in other countries, where lantana is a pest, to warrant the introduction of insect enemies. About 1909 the

seedfly was imported by the Chamber of Commerce into New Caledonia. In 1910 F. P. Jepson established the seedfly in Fiji. In 1917 the Department of Agriculture and Stock introduced the seedfly to Queensland, Australia, whence it spread to New South Wales by 1919. In 1923 H. W. Simmonds brought the two lantana *Theclas* to Fiji, and in 1928 the *Teleonemia*. In 1935 the C. S. I. R., Australia, imported *Teleonemia* and subjected it to exhaustive tests on economic plants at Canberra before liberating it in 1937.

India: In 1916 the Government of India decided to carry out an enquiry into the efficiency of the existing indigenous pests as a check on the spread of lantana before attempting the introduction of foreign fruit-destroying insects and Y. Ramachandra Rao, Entomological Assistant, Madras, spent over 2 years studying the insect fauna of lantana throughout India and Burma. He found about 150 species of insects feeding on the leaves or flowers or fruits, only a few of which are regular breeders on lantana. Amongst them is *Platyptilia pusillidactyla*, p. 694, already known to have been in India for many years. The seedfly was not found and the Imperial Entomologist, T. B. Fletcher, was strongly opposed to its introduction until it had been ascertained that it would confine its attention strictly to lantana. In 1921 the Government Entomologist, Mysore, imported the seedfly and released it at Bangalore. It was believed that this and subsequent introductions had failed but between 1932 and 1934 the fly was found throughout India from Travancore to Kangra in the Punjab and Maymyo in Burma. (p. 416). In 1941 *Teleonemia* was imported by the Forest Entomologist from Australia to Dehra Dun, p. 785, where it is being tested on economic plants, particularly verbenaceous trees, pending the adoption of a coordinated All-India policy for the extermination of lantana by biological methods.

Beeson and Chatterjee N. C., 1940, *Ind. For. Rec.*, Ent., VI, No. 3, Possibilities of control of lantana by indigenous insect pests.

Rao Y. R., 1920, *Mem. Dept. Agr. Ind.*, Ent., V, No. 6, Lantana insects in India.

Opuntia or Prickly Pear

Australia: The biological campaign against prickly pear (*Opuntia* spp.) in Australia is an outstanding example of the successful control of a pest by means of insects.

The prickly pears of the genus *Opuntia* are indigenous in north and south America and many species have been introduced into various parts of the world during the past two centuries. Several species became established in Australia of which three remained relatively minor dangers but two, *Opuntia inermis* and *O. stricta*, spread as serious weed pests infesting the wooded subcoastal and mid-inland districts of Queensland and the northern half of New South Wales, all valuable grazing and to some

extent farming land with an annual rainfall of 20 to 30 inches. At the peak of the prickly pear invasion in 1925 the infested territory occupied about sixty million acres, of which approximately fifty million acres were in Queensland. Roughly one half of the infested region comprised dense prickly pear, 3 to 5 feet high, which presented an almost impenetrable barrier over large areas. It was estimated that the weight of the prickly pear was frequently from 500 to 800 tons an acre. The remaining half of the region carried prickly pear in varying degrees of scattered infestation and marginal lands subject to periodical development of *Opuntia* seedlings. The rate of spread in 1925 was reliably estimated at million acres a year.

Biological control of the pest was suggested as early as 1899. The first definite steps were taken in 1912 when the Queensland Government appointed a Travelling Commission to explore the possibilities of control. The Commission recommended the introduction of diseases and insect enemies. A Commonwealth Prickly Pear Board was established in 1920 which was concerned solely with biological control—the investigation of the natural enemies of *Opuntia* in America and their introduction to Australia. Practically every known prickly pear region in north and south America was visited by officers of the Board. The life-history studies, breeding, testing on economic plants and despatch of the *Opuntia* insects were carried on continuously from 1921 to 1936 in the United States, Mexico and Argentina. The Board's policy was based on the idea that biological control would be most successful if a carefully selected group of species working more or less in association was established. Some 145 species of insects apparently restricted to Cactaceae were discovered but no fungus or bacterial diseases of promising value. Each species of insect was subjected in America to a series of starvation tests on many plants of economic value, and if these tests were satisfactory, again in Australia before removal from quarantine insectaries.

Between 50 and 60 species of cactus insects represented by several hundred thousand individuals were introduced to the quarantine station of the Board in Australia. Serious efforts were made to acclimatise and establish about 18 species; the acclimatisation of north American insects in a country that has opposite seasonal conditions naturally presents considerable difficulties.

Cactoblastis: In 1925 *Cactoblastis cactorum*, a phycitid moth, found in Uruguay and northern Argentina, was introduced and in 1926 the first liberations were made. *C. cactorum* lives in colonies of 20 or more caterpillars which tunnel inside the cladodes of *Opuntia* devouring everything except the vascular bundles and the thin papery cuticle. The injured segments dry out or become infected with bacterial and fungal diseases. The insect has 2

life-cycles a year of about 4 and 8 months respectively. Pupation occurs in a cocoon and eggs are deposited in long chains, or egg-sticks of 75–120 eggs, the first egg being attached to a spine or spicule on the prickly pear.

Over two million eggs were distributed in 19 localities in 1926; two years later *C. cactorum* had multiplied enormously at various centres and had begun to disperse. The value of the insect having been demonstrated, mass distribution was carried out in 1928–1930 in a cooperative campaign between the Board, the Queensland Prickly Pear Land Commission and the New South Wales Dept. of Agriculture with the assistance of landowners. In these two years three thousand million insects were released. The egg-sticks were gummed on squares of paper or were placed in paper quills which were pinned to the prickly pear cladode. Motor lorries with gangs of men distributed the eggs on all trafficable roads. Large numbers were supplied free to landowners.

After completion of the mass distribution *Cactoblastis* increased to an enormous population very quickly and the general collapse of the primary prickly pear soon followed throughout Queensland and northern New South Wales. The establishment of *Cactoblastis* throughout the infested country was virtually completed within 6 years of its introduction to Australia. The destruction of the primary growth did not signify its eradication since the butts had not disintegrated and regrowth occurred which in some localities was very heavy, as with the collapse of the food-plant the *Cactoblastis* population was suddenly decimated. In the course of a year or two the insect rapidly recovered and triumphed over the regrowth. By 1935 regrowth was almost entirely destroyed and any local appearances of seedling prickly pear or recurring growth is entirely controlled by the now more stable population of the insect. Millions of acres of previously useless land have thus been opened up for agriculture and grazing and are being made available by the State Land Authorities for occupancy under developmental conditions.

The spectacular success of *Cactoblastis* has obscured the value of the other insect enemies of *Opuntia*. The Australian entomologists consider that had *Cactoblastis* not been discovered the other insects introduced would have thinned out the dense areas and checked the fruiting and lessened the tremendous yearly increase of the plant. But these beneficial effects would have been gradual. The results obtained with cochineal insects, *Dactylopius* spp., on other species of prickly pear in India and Ceylon indicate their efficiency and the great importance of utilising the specific pest of each species of *Opuntia*.

India and Ceylon: *Dactylopius indicus*, p. 745, was introduced into India about 1795; it ran wild on *Opuntia monacantha* and practically exterminated this prickly pear by the middle of the 19th century. About this time it was introduced to Ceylon from

Madras and soon brought *C. monacantha* under control on the island. In 1913 it was introduced from Ceylon to Queensland and successfully dealt with that species of prickly pear which however was not a real pest in Australia. *D. indicus* has also been used to control *O. monacantha* in Mauritius.

Dactylopius tomentosus, p. 746, was imported to Australia from Mexico and Texas; various strains of the species were effective in thinning out dense scrubs of *O. tomentosa* and *O. streptacantha*, as well as providing an appreciable measure of control of *O. inermis* and *O. stricta* in spite of the existence of its predator, *Cryptolaemus montrouzieri* (Coccinellidae). *D. tomentosus* was introduced to Ceylon in 1924 whence it was brought to south India in 1926 and has since been propagated throughout India on *Opuntia dillenii* and *O. elatior* (=nigricans). *Cactoblastis cactorum* failed to bring about permanent control of *Opuntia aurantiaca*, *O. tomentosa* and *O. streptacantha* in Australia and it does not necessarily follow that it would be effective on *Opuntia dillenii* and *O. elatior* in India.

In Madagascar *O. dillenii* has been affected by the accidental entry in 1924 of *Dactylopius coccus* from the Island of Reunion.

Other weeds

Species of the composite genus *Xanthium*, or cockle burrs, are pests in sheep-rearing districts in Australia; the burr is covered with strong hooks which catch in the wool of the sheep. A species, *X. strumarium*, abundant in India and becoming a pest of cattle, was the subject of attention recently as part of a general search for pests of cockle burrs throughout the world.

Nothing is known of the pests of other alien weeds in India, such as *Eupatorium* spp., Assam lota, *Ageratum*.

6. MECHANICAL CONTROL

SPECIAL operations which catch or kill insects by mechanical or physical action are classed in this section of artificial control. Some of them are of general application against various types of pests but most of those suitable for use in forestry are devised for a limited purpose and are prescribed in detail for the species concerned in a later section of Part Two.

Hand-collection and destruction: Collecting and destroying injurious insects by hand is the simplest and most effective remedy in many cases, e.g., for caterpillars and large beetles in forest nurseries, cockchafer grubs and crickets in seed-beds. The use of hand-nets or drag-nets for small or active insects is an extension of the same, e.g., for beetle defoliators, grasshoppers and plant-hoppers. Probes of wire or other flexible material are used for poking into the tunnels of wood-borers, e.g., *Zeuzera*, *Batocera*.

Barriers and repellents: Trenches, water-channels

and smooth vertical surfaces are used to prevent the movement of crawling insects. Mosquito nets, wire gauze windows and doors, etc , are protective devices used against biting flies, house-flies and termites. Varnish and oils of various sorts are used to prevent egg-laying, e.g., by Bostrychidae, or Culicidae. Against termites impregnation of timber with oils or water-soluble preservatives is a form of repellent barrier and metal shields or concrete courses are physical barriers in buildings. Grease-bands or sticky bands are used on tree trunks to prevent the ascent of e.g., wingless females of Geometridae, mealy bugs (*Drosicha*), ants (Formicidae). Essential oils in grease or vaseline are applied to the skin against biting flies. The method of preparation and use of these materials is described under 7, Chemical Control, pp. 859—861.

Traps: Green logs or billets of the food-plant are used as traps for borers which oviposit on bark, e.g., *Hoplocerambyx, Pagiophloeus*. Sunken tins or pots catch ground-insects. White sheets attract *Calopepla*.

Bark: Removing the bark from freshly felled logs is a positive method of preventing oviposition by some groups of bark-borers. Leaving the bark on and keeping it alive by shade and moisture prevents oviposition by other groups of borers.

Pruning: Removing bored shoots and branches is needed for some types of borers; pruning dead branches and snags and painting the wounds is a remedy for bark-eating caterpillars.

Submersion: Logs wholly immersed in water are protected against attack. Submersion can also be used to kill borers already inside the wood or bark.

Heating: Accelerated air-seasoning to reduce the moisture-content of timber prevents attack by pinhole borers. Exposure to sunheat kills borers in the bark. Kiln-seasoning can be used to sterilise timber already infested. Charring is one way of making an impassible barrier on butt ends of poles.

Light-traps: These vary from a kerosene oil lantern over a tray of water to power-driven ultra violet ray beacons fitted with suction fans devised for mosquito control. So far no use has been made of light traps for forest insect pests.

7. CHEMICAL CONTROL

By their mode of action insecticides should be classed in 2 groups: direct and protective. For the forest officer a convenient grouping is: contact poisons, stomach poisons, fumigants and wood preservatives. The methods of application are spraying, dusting, fumigating and impregnating. The use of aeroplanes for dusting forests has been developed in Europe and North America but is unknown in the East. The first 3 methods have been extensively used against pests and diseases of agricultural crops, fruit-trees, tea, coffee, rubber, etc., but have a

limited application in tropical forests. In fact, almost the only scope for insecticides is in the semi-agricultural phases of forestry, e.g., in nurseries, regeneration areas and in valuable stands faced with extinction.

Contact poisons

The direct acting or contact poisons kill by contact with the body of the insect or through the tracheae; they are chiefly used against sucking insects but also against soft-bodied chewing insects, and in the form of sprays or dusts. Repellents and sticky barriers may be included here.

Sprays and dusts

Crude-oil emulsion: Obtainable readymade as a semi-solid emulsion in 5 gallon drums. The ingredients are a heavy soap made from fish oil and crude heavy petroleum. It keeps well; free black oil floating on the surface of old stock indicates that it has deteriorated. Make up to 160 oz. of emulsion in 100 galls. of water. Crude oil emulsion is used as a fine mist spray for all kinds of sucking insects also as a dilute wash for ticks, fleas, lice, etc., also as a soil-poison or deterrent for termites watered on or applied through the irrigation channel and also as a fluid for dipping cuttings. It can be homemade from Diesel oil 6 galls. potash fish oil or vegetable soap 320 oz., water 100 galls. Slice up the soap and dissolve in 20 galls. hot water and add 6 galls. oil; pump the mixture at a pressure of 60 lbs. with a bucket-pump into another container, and then similarly pump it back into the first; repeat 2 or 3 times until the mixture becomes a homogeneous thick cream with no free oil on the surface. Add the remaining 80 gallons of water for spraying.

Fish-oil-rosin soap, etc.,: A brown semi-solid soap manufactured in soap-factories and variable in price and composition. The spray mixture is 200 to 400 oz. of soap dissolved in 100 galls. of water; used for Aphidae, Coccidae and the nymphs of Jassidae, Pentatomidae and sucking insects in general. A soap made from the oil of seeds of *Bassia latifolia* or *Pongamia glabra* answers the same purpose.

Kerosene-oil emulsion: The formula is 40 oz. soap, 10 galls. kerosene and 100 galls. water. Slice up $\frac{1}{2}$ lb. bar soap very finely and dissolve in one gallon of water by boiling; remove from the fire and add 2 gallons of kerosene oil. Violently agitate the mixture by stirring or by pumping back on itself with a spray pump, using a coarse jet or removing the nozzle, until thoroughly emulsified. Keep as a stock solution which is diluted with 20 to 30 times its bulk of water before use. To make the spray more adhesive on plants or on the bodies of insects add a sticker such as 1–2 ounces of glue, flour paste or casein. If very hard water is used less water or more soap is needed. This is a standard

contact insecticide for various kinds of soft-bodied insects.

Pyrethrum: Used as a dry dust or as an extract in hot water or in kerosene oil; it is the basis of flea powders and fly sprays. Only available in the form of proprietary extracts or compounds with which particulars as to strengths and uses are supplied. Possible substitutes for it in India are dusts made from *Derris* root, *Mundulea suberosa* stem bark or *Tephrosia candida* and *T. villosa* seeds.

Rosin-soda: The formula is rosin 1,000 oz., washing soda 170 oz., water 100 gallons. Mix the powdered rosin and soda in a vessel and add water to cover it. Boil slowly and add warm water from time to time until the liquid is a clear dark brown, remove and strain through muslin. If properly prepared a drop of the compound will mix thoroughly with cold water; if insufficiently boiled it will form a milky emulsion with water. For use dilute with 5–8 parts of water.

Soap solution: Ordinary country bar soap is the cheapest; potash soaps remain in solution better and are more easily sprayed and more effective than soaps made with caustic soda. Formula, 320 oz. of sliced soap dissolved in 100 gall. of water for soft-bodied fragile insects.

Tobacco: Nicotine is available as nicotine sulphate or is obtained as a crude extract from tobacco leaves. The best proprietary brands contain about 40 percent by weight of nicotine. Average formula is 1 pint nicotine sulphate, 64 oz. soap in 100 galls. water, up to $2\frac{1}{2}+80+100$. Country tobacco leaves vary greatly in their nicotine-content but for average purposes the formula is 200 oz. dry leaf and 50 oz. soap in 100 galls. water prepared as follows: boil 1 lb. of leaf and 4 oz. soap in a gallon of water or steep it in cold water for a day and night and dilute for use with 7 galls. water. Dry sieved tobacco dust mixed with an equal quantity of lime or sulphur can be used for dusting in dry weather. Nicotine sulphate solution is better than tobacco leaf for keeping off leeches.

Repellents

Bordeaux mixture: is frequently used as a repellent to prevent feeding by defoliators or sap-suckers; the formula is variable but an average one is copper sulphate 130 oz., quick lime 160 oz., water 100 galls. Dissolve the sulphate in part of the water, say 90 gallons, in a wooden or earthen vessel; slake the lime separately by adding just sufficient water and then add the remainder of the 10 gallons gradually, stirring well; strain and add the lime water to the sulphate solution.

Repellents for biting flies: For the protection of human beings against the bites of mosquitoes (Culicidae), midges (Ceratopogonidae), sandflies (Psychodidae), potu flies (Simuliidae), etc., scores of mixtures for smearing on the skin have been

invented. The formula most likely to suit a particular forest officer depends on the reaction of his skin to vaselines and oils, on his perspiration, on climatic conditions as well as on the particular species of fly; among the following there should be something suitable for each.

Formula 1, oil of thyme 1 part, concentrated extract of pyrethrum in mineral oil (extract of about 1/5th lb. of pyrethrum flowers per fluid ounce of concentrate) 2 parts, castor oil 4–6 parts. A less oily mixture may be made by substituting olive oil for castor oil but the protection does not last so long. Cover the exposed parts of the body; the insects may alight but will not bite until the repellent has evaporated or been rubbed off; it should last for 3–5 hours.

Formula 2, equal parts of oil of aniseed, eucalyptus and terebinth in boracic acid ointment (for sandflies).

Formula 3, oil of citronella 2 parts, oil of camphor 1, oil of cedar or pine 1, in vaseline, white petroleum jelly, salad oil or lanoline 8 parts (for mosquitoes; may be used out of doors by day or if sleeping without a net; can be applied to all exposed parts of the body, the hair, and to clothing or bed linen).

Formula 4, equal parts of oil of citronella, oil of eucalyptus, turpentine and methylated spirits (for temporary use, readily evaporating).

Formula 5, high speed Diesel oil 92 parts, pine oil 3 parts, concentrated extract of pyrethrum 5 parts (for horse and cattle flies and if riding a horse; can be applied with a flit-gun).

Fly spray: For house flies and mosquitoes the formula is pyrethrum extract 6 parts, oil of citronella 2, carbon tetrachloride 49, white kerosene 43 parts. This is an economical and non-inflammable spray.

Sticky bands

Grease-bands, sticky bands, tree-bands or tanglefoot are used on the trunks of trees, etc., as barriers to prevent the ascent or descent of crawling insects. The composition depends on the surface on which the band is applied and the climate in which it is used. On an absorbent surface the fluid parts are likely to be absorbed; in a hot climate the material may melt and run; in a cold climate it may become hard and lose its stickiness; in dusty air it may film over. Remove bark flakes and smooth the surface of the trunk before application; spread the composition with a wide stiff brush or a wooden spatula in a band 2 or 3 inches wide. For very sensitive bark the band should be spread on grease-proof paper which is tied round the middle with string; or a band of melted paraffin wax may be applied to the bark and the mixture spread over it.

Rosin-castor oil: The formula is powdered rosin 6–12 parts, crude castor oil 5 parts by weight. Heat the oil in a vessel over

a fire until a faint blue smoke rises and add the powdered rosin, gradually stirring well to obtain a thorough mixture; the oil must not be overheated otherwise the mixture hardens rapidly in use. A more controlled method is to mix the rosin and oil cold and pour the thick paste into a vessel placed in a larger one containing boiling water; boil the water for 15–20 minutes, stirring constantly and vigorously as the rosin dissolves in the oil. For use in cold climates 6–7 parts of rosin are needed for a mixture that is sticky during the day; for use in high temperatures increase the rosin or add 1–2 parts of beeswax to prevent melting and running. If crude resin is available instead of rosin, heat it slowly for a long time until all the turpentine evaporates and its bulk is reduced to about half; cool the resulting rosin and powder it. To restore the stickness of a dusty or dry band scrape or comb it and paint with crude castor oil.

Rosin-neem oil: The formula is powdered rosin 120 parts, neem oil 50 parts, crude vaseline 10 parts and crude carbolic acid 1 part. This mixture should be used on a band of grease-proof paper, spread on the paper while hot and fastened to the trunk of the tree, overlapping, tied with string. Grease-proof paper can be made by soaking strong packing paper in a solution of glue 1 part and water 3 parts and drying it before use. (*Dept. Agr.*, U.P., Bull. No. 3, Fruit Series, 1933). Used as a tree-band for *Drosicha* (Coccidae).

Tar-crude oil emulsion: A mixture of equal parts smeared on a band of jute sacking, sann hemp rope or thick munj rope and tied round a tree in a band 6–9 inches wide, is a barrier against *Drosicha*; it needs renewal once a fortnight.

Tar-pitch-oil: To prevent caterpillars shaken from trees from climbing up again, band the trunk with Plecoptera mixture; the formula is coal tar 37½, pitch or asphalt 12½, dry soap 7½, castor oil 10, alluvium or multani earth 12 parts by weight. The ingredients are heated and constantly stirred in a cauldron over a wood-fire until viscid. Two coolies can mix and prepare 10 maunds a day.

Stomach poisons

The protective insecticides are used mainly against chewing insects which eat the poison on the food-plant and are killed by its action on the alimentary system: at the same time they act partially by deterring feeding and cause the insect to starve.

Arsenates of calcium and lead: Both are white insoluble powders and very poisonous to man and domestic animals. Compared with lead arsenate the calcium salt makes a better lighter powder for use as a dust; the lead arsenate makes the better spray suspension for use of fluid sprays. Dried calcium arsenates contain about 40–45 percent arsenic oxide while dried lead arsenates contain only 31–32 percent arsenic oxide. The

transit costs are less for the powder with the lighter metallic radicle and the lower water-content. Calcium arsenate is somewhat cheaper. Lead arsenates are relatively stable and do not change much after spraying on foliage; the basic calcium arsenates decompose to dicalcium hydrogen arsenate and calcium carbonate. Commercial calcium arsenates are prepared with an excess of lime and spray injury to foliage is thereby reduced. Both are available in paste or powder form.

The formula for a spray is 50 oz. lead arsenate powder or 100 oz. paste in 100 galls. water; its efficiency is increased by adding 75 oz. lime and 150 oz. molasses. When using powder it should first be thoroughly mixed with a small amount of water to make a thin uniform paste which is poured into the vessel holding the rest of the water. The formula for a dust is, 1 part arsenate with 5–10 parts hydrated lime, or wood-ashes or alluvial earth.

Neem leaves: Extract of the leaves of *Melia indica* (neem, margosa tree) is particularly valuable as a deterrent spray for locusts and grasshoppers. The active principle is extracted from the desiccated leaves with hot water or methylated spirit. To the greenish-black, syrupy or pasty extract 20 percent glycerine is added to facilitate emulsification in water; it is used in a dilution of 1 percent. Sprayed foliage resists the action of intense sunlight and moderate rainfall and is not poisonous to animals. Dried leaves or powdered leaves are also used as a repellent (*Ind. For.*, 1940 LXVI, pp. 53–58).

Paris green: A bright emerald green powder (mainly copper acetate and copper arsenite); it should contain over 50 percent arsenious oxide; a good quality averages 55 percent; solubility in water should not exceed 3 percent. The formula for a spray is Paris green 8–10 oz., quicklime 32 oz., water 100 gallons. The quicklime is added to prevent burning of foliage. Mix the poison with a small quantity of water into a thin paste and add all the quicklime and remix; then add the remaining water; agitate the mixture thoroughly before use. The formula for a dust is Paris green 1 part, slaked lime 5–10 parts by volume; other diluents are alluvial earth, brick-dust, fine sand, wood-ashes, powdered soapstone, talc. For use as a mosquito larvicide it should be mixed with soapstone or slaked lime at 1 to 20–40, or with road-dust, fine alluvium, etc. at 1 to 100. Note: Men mixing Paris green and working sprayers or dusters should protect the eyes with goggles and the mouth and nose with cloth.

Sodium fluoride: is used as a dust or in dry baits, e.g., against cockroaches, or as an ingredient in a spray or for wood-preservation; see later under Bostrychidae.

Spreaders and stickers: To improve the spreading, sticking or wetting efficiency of sprays used on different kinds of foliage in different weather conditions it may be necessary to add an

agent such as soap, saponin, mucilage of prickly pear, linseed oil, molasses, casein. The most suitable for the particular case must be determined by experiment.

Fumigants

In fumigation the chemical is applied in a gaseous form by exposing a volatile liquid or solid. The remedy is used in air-tight receptacles or rooms to sterilise infested products or in the soil to kill soil-insects.

Carbon disulphide: A colourless liquid vapourising to a foul-smelling, highly inflammable, poisonous gas; in mixture with air it forms an explosive gas. It is commonly employed because it can be used in almost any type of container or chamber. Mixed with carbon tetrachloride or sulphur dioxide there is less fire risk; the mixture is most effective at temperatures of 70° F. and over. The dosage is 60–80 oz. per 1,000 cuft. of space for 36 hours. It is suitable for the fumigation of stored seeds, grain, etc. in large or small containers. 16 oz. per 1,000 cuft. is enough for bookworm.

Calcium cyanide: Is available in granules or powder under the name cyanogas; when acted upon by moisture in the air it gives off hydrogen cyanide or hydrocyanic acid gas. It is used as a soil-fumigant or in the burrows of rats, porcupines, etc. Hydrogen cyanide can also be obtained adsorbed on a mineral earth or on papier-mache discs.

Ethylene dichloride-carbon tetrachloride: The formula is 1 part carbon tetrachloride to 3 parts ethylene dichloride by volume. (The latter is also known as ethylene chloride, S dichloroethane, alpha or beta-dichloroethane). It is a colourless liquid $1\frac{1}{4}$ times as heavy as water giving a vapour 3 times as heavy as air. The mixture is non-inflammable, non-injurious to furniture or fabrics, furs, carpets, not corrosive or bleaching, and not dangerous to human life, relatively cheap and 5 times as toxic to insects as carbon tetrachloride alone; it works best at 80°–85° F. and its use below 70°F. is not recommended. The formula is 100 oz per 1,000 cuft. of space which is 100 percent lethal in a gas-tight chamber for a 24-hour exposure at 85°F. For general fumigation at lower temperatures up to 220 oz. per 1000 cuft. should be used.

Ethylene dichloride emulsion: The formula is 9 parts by volume of ethylene dichloride in 1 part of the fish oil-potash soap (containing about 30 percent soap). It may be prepared by adding 8 parts water to 1 part fish oil soap and then mixing 9 parts ethylene dichloride; emulsify by pumping the cold mixture a few times, which process simplifies the emulsification and prevents reversal or breaking down of the emulsion. The mixture is a 50 percent dilution; in average use as a soil fumigant a 3 to 10 percent dilution is suitable.

Napthalene: Obtainable as crude or centrifuged napthalene crystals (with oily impurities), or as napthalene flakes or balls. As a soil-fumigant or disinfectant of rooms, floors, shelves, cupboards, etc., the crude napthalene is suitable and cheaper. For insect collections, libraries, clothing and fabrics, furniture, etc., napthalene flakes are suitable and can be used without damage of any sort. The dosage is a quantity enough to produce and maintain an easily detected smell of napthalene.

Ortho- or para-dichlorobenzene: In crystal or liquid form is used for the sterilisation of wooden articles attacked by powder-post beetles and other borers. (see under control of Bostrychidae).

Wood preservatives

The types of preservative that can be used for the protection of wood against attack by insects are classed as oil, soluble in water and soluble in organic solvents. The methods of treatment of the wood with any of these preservatives can be classed as impregnation, immersion, and spraying or brushing. (a) Impregnation under pressure by the 'full cell' process must be done in a suitable pressure-treating plant. (b) Immersion requires a tank or pair of tanks to hold the liquid and the accessory facilities for loading and unloading and draining the pieces of wood treated. The preservative liquid may be used cold or may be heated by means of steam pipes or grate and flue beneath the tank or by a circulating siphon heated externally. The period of immersion may vary from momentary, e.g., 10 seconds or the time needed to fill and empty the treating tank, to several hours, i.e., a day and night. (c) For material so situated or stored that it cannot be taken to a tank for immersion, or timber that is built in place, smearing, brushing or spraying the liquid on the accessible surfaces are the only means available.

The relative merits of preservative treatments are recorded in literature on wood preservation; references will be found in the later section dealing with the Control of Termites; see also, F.R.I., Pamphlet No. 1, 1940, *A short note on wood preservation for users in India.* Generally speaking with green timbers better penetration is obtained from the water-soluble preservatives than from creosote and oil mixtures, but the former are liable to leach out of timber used out-of-doors. For protection of air-seasoned timber solely against borers a cold immersion treatment has to suffice because of the limitations of cost and equipment. Where protection against termites and decay must also be secured it becomes a problem of wood-preservation rather than of economic entomology.

Hydrocarbon oils

Creosote: Coaltar creosote is the standard preservative for sleepers and constructional timber generally because of its fungi-

cidal and repellent properties. The cost is about Rs 150 per ton naked or Rs. 1 to 2 per gallon in small containers, consequently it is usually diluted with cheaper oils, e g ,

Fuel oil: In the group of fuel oils are included products marketed as crude oil, diesel oil heavy and light, fuel oil, furnace oil, etc. at prices between Rs. 45 and 55 per ton naked. These vary in viscosity and smell which are the characteristics of most value in preventing attack by borers

Water-soluble salts

Boric acid: is obtained as a very fine white crystalline powder, granulated, or as fairly coarse white crystals; the granulated or crystalline substances are more readily dissolved than the powder. The strength of the treating solution should be 1 25 percent boric acid. The lethal concentration as a percentage of the oven-dry weight of the wood is 0·12 percent for boric acid and 0 2 percent for borax alone The absorption and penetration of boric acid into green veneer is adequate and rapid in a hot solution (200–212°F.); see under Lyctus

Sodium fluosilicate (silicofluoride): At low concentrations this is the most toxic of the chemicals used for Lyctus and similar borers. When used as low as 1/40th of a lb. of the dry salt per cuft. of wood, which is equivalent to 0 06 percent of the salt based on the air-dry weight of the wood, complete immunity is conferred. In using it there is danger of fluorine intoxication and osteosclerosis caused by the dust or vapours, but the disease results from cumulative poisoning and may take several years to affect those workers constantly exposed to it day by day. Sodium fluosilicate is therefore not recommended for regular use as a wood preservative in factories or wood-working industries unless special precautions are taken to protect the workers against inhalation or ingestion of dust containing fluorine. For temporary or intermittent use, on the other hand, the risk is not serious and the chemical may be used for special or isolated jobs

Zinc chloride used in solutions up to 8 percent is almost the cheapest salt for wood preservation; at least ½ lb of dry salt per cuft. of wood is required for protection against decay. It differs markedly in its action on Lyctus larvae, at concentrations of 0·7 percent zinc chloride they can operate but die early, at 0 14 percent larval damage is only slight Because it varies in its action in checking the development of larval galleries it is not recommended for treatment of plywood, but since it prevents pupation it is useful for checking local breeding in packing cases and planks, scantlings, etc

Spraying and dusting equipment.

The equipment used in applying an insecticide varies from very simple devices to extremely elaborate machinery. Expensive machines are not justified in forest divisions unless they are regu-

larly used or precautions are taken against deterioration of washers, valves and hoses and against corrosion of the pump.

Spraying machines: For occasional work the smallest and simplest spraying machines are i, the atomiser or flit-gun as used for houseflies and mosquitoes, ii, the hand-pump or syringe, and iii, the bucket-pump or stirrup-pump.

ii. There are two patterns of hand-pump one in which the pump has to be refilled after each stroke by dipping the nozzle into a vessel-containing the insecticide, and another in which the pump refills continuously through a rubber hose leading from the cylinder into the vessel of insecticide.

iii. The cylinder of the stirrup-pump is placed inside the bucket or other container and is supported vertically by a clamp and a strong stirrup which is pressed on the ground by the operator's foot; the nozzle is at the end of a hose attached to the cylinder. Both patterns ii and iii can be operated by one man. In the hand-pump both hands are used for aiming and discharging and the operator has more freedom of movement. In the stirrup-pump one hand is used to work the pump and one to aim the nozzle and the operator's position is fixed by his foot on the stirrup; if this pump is fitted with a long hose and extension tubes and is worked by two men the range of operation is considerably increased. A variety of nozzles can be used forming a solid jet or a coarse spray or a mist. The valve-action is either one way or has an air-chamber giving a continuous discharge. The stronger pumps can deliver a jet to a height of 30 feet from the ground. Costs are between Rs. 20 and 40.

Tall trees cannot be sprayed from the ground unless a power operated sprayer is used. A machine with a 2 H.P. engine developing 150 lbs pressure and a straight bore nozzle delivering a solid stream breaking at 80 feet or so would cost about Rs. 1,200–1,500.

Dusting machines: Satisfactory dusting of low plants can be done with a tin or basket covered with a loose-meshed cloth. For dusting high saplings a sacking or cloth bag holding 2 or 3 pounds, tied at both ends to the top of a bamboo pole is quite effective in the hands of an intelligent operator who takes account of the wind and the spread of the cloud of dust. Under favourable weather conditions one man can treat 25 acres a day and distribute the dust uniformly. A hand-duster carrying about 2 lbs. of powder and operated by means of a double-handled bellows costs Rs. 5-10 to make; the metal nozzle ends in a fan-shaped adjustable spreader.

Fumigating machines: For injection of fumigants into the soil there are special appliances but a simple thumb syringe and a hollow tube or even a crow-bar are sufficient. For producing sulphur dioxide gas the white ant exterminators described later under Control of Termites, Isoptera, are used. For fumigation of

stored seeds, etc., air-tight containers are best made from tin or galvanised iron (usually called zinc): see under control of Bruchidae.

NOTE: *For current prices of chemicals and apparatus and the addresses of suppliers consult the Forest Research Institute or the Director of Industries.*

TEXT BOOKS, ETC., ON CHEMICAL CONTROL:

Ayyar T. V. R., 1940, *Hand book of economic entomology for south India*, pp. 528, figs. 413.

Ghosh C C., 1940, *Insect pests of Burma*, pp. 216+xv, 106 figs., 87 pls.

Husain M. A., 1936, *Agr. Livestock Ind.*, VI, pp. 127-138, 44 figs, Combiting insect pests.

Rahman K. A., 1940, *Punjab Agr. Mag.*, VII, pp. 98, Insect pest number.

CONTROL MEASURES

"Let the jury consider their verdict," the King said
"No, no!" said the Queen. "Sentence first—verdict afterwards."
"Stuff and nonsense!," said Alice loudly. "The idea of having the sentence first!"
(Alice in Wonderland)

Before he can begin to consider the possibility of control measures for any insect pest under any conditions the forest officer must decide that (a) the mortality or damage is due to insect action and not to other causes, and (b) it is continuously active and not all over when detected; or he must supply sufficient evidence to enable a research officer to give a verdict. An effective remedy must be based on an adequate diagnosis: the sentence must follow the verdict. It is therefore not superfluous to emphasise 3 obvious and essential prerequisites to control operations:—

i. Make sure that the trouble is due to insects and that need for control actually exists and persists.
ii. Get accurate identifications of the species involved.
iii. Discover the outbreak in its early stages and ascertain its full extent and spread.

The sections immediately following amplify the importance of these three rules.

Diseases and dying-off

An important principle of forest protection in India is the accurate diagnosis of the causes of dying-off of trees and a correct assessment of the role of insects in the interaction of various factors. (Rule i). Disease in plants, as in animals, is due to maladjustment to their environment. The immediate cause of death of a plant may be the attack of a fungal or bacterial parasite. But the more remote causes are various, depending usually on the lack of power to respond to changes in the environment; since the biotic environment is most liable to

change, death is most often caused in this way. One stage of development of the plant-community gives way to the next until a climax or fairly stable condition is reached. When man supervenes his interference always tends to send back the plant-succession; climax stages are destroyed and earlier stages take their place (pp. 828-832).

To ensure a continuous supply of water and mineral nutrients into the roots of a healthy tree root-growth must continue and new root-soil contacts must be established. Nevertheless the forester is apt to suppose that the site-conditions under which a tree started life remain practically constant during its life, whereas in reality changes in drainage, aeration, fertility and the eco-climate may take place gradually or abruptly and remain entirely unperceived. It is easy but wrong to assign the dying-off and die-back of forest trees unquestionably to primary attack by borers or sap-suckers; today we should be very reluctant to draw the conclusion. On the contrary, the evidence presented by a dead or dying tree full of borers or covered with sap-suckers tells a different story. Insect activity in such cases indicates a loss of vigour on the part of the tree due to deterioration in its environment and the onset of disease due to causative agents other than insects.

The following data represent the current views of plant pathologists on the relative importance of insects, fungi, viroses and growth-conditions in the dying-off and die-back of the more important timber trees.

Dying-off of Cedrus deodara and other conifers

Healthy poles and trees of *Cedrus deodara* may be killed off by (a) primary attack of *Ips longifolia*, *Polygraphus major*, *Scolytus major*, etc. (Scolytidae) in abnormal epidemic outbreaks, and (b) complete defoliation by *Ectropis deodarae*, p. 598, repeated for 2 or 3 years in succession. Mortality in these circumstances is definitely concentrated in groups of trees (varying in size from a square chain to several acres) in which everything is killed outright except at the boundaries of the group where there is evidence of failed borer-attacks callused over. Dying-off which is not due to primary insect-attack occurs in irregular groups or scattered trees which exhibit a variety of symptoms with a variable secondary borer-fauna.

The symptoms of death ascribable primarily to the failure of the roots are: (a) roots all dead, in some cases with incipient decay, or else the majority of the surface-roots dead and the deeper survivors with their lateral branchlets dead; protracted dying-off of roots is indicated by borings of cerambycid and curculionid larvae of more than a season old; (b) root-collar usually marked by pockets of resin; (c) bole living or green from soil-level upwards for a variable distance, the living portion sharply separated from the dead subterranean parts; (d) green part of bole without insect attack or with scattered egg-tunnels of *Scolytus major* and *Tetropium oreinum*, p. 211, and resin-flow; (e) upper bole and crown branches with heavy infestation of *Scolytus major* and/or *Sphenoptera aterrima*, p. 118; (f) branchlets with initial tunnels of *Pityophthorus deodara*, p. 379, and needles yellow, withered or fallen.

Some or all of these symptoms occur when the soil is excessively wet, shaded and carries a deep layer of humus and needles; as also when the locality is dry, exposed and rocky.

Fungi: The root-rotting and stem-rotting fungi of conifers are *Armillaria mellea* and *Fomes annosus*; both are pathogenic. Young trees of *Cedrus deodara* and *Pinus excelsa* in plantations are killed mainly by *Fomes annosus* and mature trees of *Picea morinda* are killed by *Armillaria mellea* assisted by *Eucosma hypsidryas*, p. 589. The instability of the environment of coniferous forests and the importance of factors predisposing to disease are illustrated in a case recorded by Bagchee.

In Jaunsar, U.P., plantations of deodar and pine were made on abandoned cultivation terraces previously occupied by agricultural crops or second growth forest. The soil of the agricultural or of the old forest land was highly acid. During the management of the early stages of the plantations from the time of transplanting up to the pole stage the ground was covered with a thick growth of weeds, adding to the thickness of the humus previously present and increasing the acidity of the soil. This factor coupled with deficient drainage of the subsoil (the terraces usually dip towards the hillside), and with the absence of sunlight in crowded plantations, results in the accumulation of soil-moisture and the asphyxiation of many of the deeper roots of the trees. In young plantations the symptoms of die-back are early apparent and infestation by *Fomes annosus* is widespread in the pole stage.

Trametes pini is responsible for the brown heart-rot of conifers especially *Cedrus deodara* and *Pinus excelsa*; infection takes place through old branch wounds.

Rusts: *Peridermium cedri*, the deodar needle rust, causes 'witches broom', early shedding of needles, stunted growth and die-back of *Cedrus deodara*. *Peridermium indicum* and *P. himalayense* occur on *Pinus excelsa* and *P. longifolia* respectively; the bark of twigs and stems are infected and eventually cankered, resulting in the stagnation and final death of young saplings and poles. In *Pinus longifolia* the diseased bark and the adjacent parts of the stem are tunnelled by larvae of *Cryptorrhynchus rufescens*, p. 265, and pyralid caterpillars; Scolytidae arrive as a secondary infestation.

Dying-off of Dalbergia sissoo

Healthy trees of *Dalbergia sissoo* growing in natural forest are not killed by primary insect attack. When grown under the adverse conditions of the irrigated shisham plantations in the Punjab the trees die off or die back from (a) soil-conditions that are unsuitable physically and chemically, (b) drought or insufficient irrigation, (c) frost, (d) root disease, *Fusarium* sp.. Superimposed on these disabilities, (each of which may alone be fatal under certain conditions), are the attacks of defoliators and borers which are contributory but definitely secondary factors, c.f., pp. 817, 840. Where two or more of these agencies are acting together it is difficult to isolate characteristic symptoms for each.

The symptoms of dying back due to frost and to drought can usually be separated from those due to defoliation; in the former cases the plants are

low and bushy due to repeated formation of new shoots from the stump and base of the stem and the branchlets are curved inwards towards the stem owing to gradual and differential desiccation; in the case of defoliation by *Plecoptera reflexa* and *Dichomeris eridantis* there is no such deformation of the branchlets and the new flush and new shoot-production is predominantly from the crown. Extensive dying-off of shisham in the irrigated plantations was in the past erroneously ascribed to defoliation.

Borer attack is characterised by two features: (a) The bostrychid beetles, *Sinoxylon* spp., and *Cladobrostis melitricha*, p. 564, sever the branches by means of evident concave or conical cuts transverse to the axis, and the branch below the cut remains green. (b) When *Sinoxylon* beetles bore into the bole a circular hole is made from which a thick black fluid exudes and runs down the bark; the tunnels of the larvae of *Perissus dalbergiae*, p. 199, also produce exudations of black gum together with fine wood and bark dust. The attack of these borers is an indication of reduced resistance on the part of the tree and is definitely secondary. Primary or epidemic mass-attacks on relatively healthy trees may develop in the vicinity of an unhealthy crop, if local multiplication in the latter is allowed to continue unchecked.

Fungi: Mortality of shisham is definitely due to root-disease in the Punjab and the United Provinces. The root- and collar-rotting fungi, *Ganoderma lucidum* and *Polyporus gilvus*, are invariably found at the bases of dead and dying trees of all ages but they play only a secondary part. The primary organism is a species of *Fusarium*; this is the only instance in which a forest tree is known to be fatally attacked by a wilt due to a *Fusarium* (Bagchee).

Dying-off of Shorea robusta

Borers: Out of the extensive borer-fauna of *Shorea robusta* only one species, *Hoplocerambyx spinicornis*, is capable of killing healthy trees. The secondary borers may accelerate the death of moribund trees, possibly causing death to occur a year or two earlier than would happen in their absence. No species of defoliators or sap suckers have been incriminated in the wholesale dying-off of sal.

The borers associated with dying saplings, poles and trees of sal produce fairly characteristic symptoms. Primary attack due to *Hoplocerambyx* shows the following symptoms:

(a) dying-off from the crown downwards by sudden withering of the foliage in the autumn or spring, (b) profuse exudation of resin (*ral* or *dammar*) at points where the first stage larvae bore in the bark, (c) healthy condition of the roots.

The secondary borer-fauna comprises many species of Bostrychidae, Buprestidae, Cerambycidae, Platypodidae, Scolytidae, Tineidae and other families. It varies very considerably in its composition in different localities and in individual trees. The general symptoms of secondary borer attack are:

(a) dying-off is preceded by drying-up of the crown or stagheadedness, (b) there is no sudden withering of foliage, (c) the bark remains closely

attached to the bole, or separates loosely in patches with discoloration of the sapwood, (d) resin is not exuded at points of oviposition, (e) the roots are dead in parts or diseased, the wood being invaded by hyphae, (f) the distribution of species of borers is not constant from tree to tree and it is rare for one species to be greatly predominant over the others.

The characteristic borer-fauna of stagheaded and dried-out crowns comprises *Acmaeodera stictipennis* and *Chrysobothris beesoni* pp. 114, 116, *Sinoxylon anale* and *Xylodectes ornatus*, pp. 85, 95, and *Xylotrechus smei*, p. 215. In the larger branches and boles of such trees other characteristic borers are *Aeolesthes holosericea*, *Coptops aedificator* and *Diorthus cinereus* (Cerambycidae). The occurrence of these species, coupled with the absence of other groups, is a good indication that the trees either died of drought or were attacked after the crown and bole had begun to dry out. A species indicating dry conditions of peculiar nature is *Gerontha captiosella*, p. 702, which is sometimes associated with a saprophytic bark-fungus, *Hypoxylon annulatum*, that forms a charcoal-like encrustation beneath the outer dead bark, easily mistakeable for scorching by ground-fires. *Sphaerotrypes siwalikensis*, p. 386, is a good indicator of the condition of the bark at the time of attack.

In localities of high-rainfall where drought or deficiency in subsoil moisture-content are not primary factors, the indicator species in the borer-fauna are *Crossotarsus saundersi* and *Diacavus furtivus*, pp. 330, 334, many *Xyleborus* spp (Scolytidae), *Dialeges pauper* and *Xylotrechus buqueti*, pp. 160, 213. In the forests of the wet sal type and in some of the moist sal type the root-disease, *Polyporus shoreae*, is frequently accompanied by secondary damage to deep roots by termites, prionine larvae and *Xyleborus* spp. Secondary borer-attack above ground is distinguished from primary epidemic attack in these regions by the diversity of the incidence of the constituent species. When the analysis of a series of sample trees shows that no species of borer is outstandingly abundant, or, if abundant, is absent from a percentage of the dead trees then a diagnosis of secondary attack is justified.

F u n g i: The most important fungi of *Shorea robusta* are *Polyporus shoreae*, *Polystictus tabacinus*, *Trametes incerta*, *Fomes fastuosus*, *F. lamaoensis*, *F. melanoporus* and *F. tricolor*. Of these *P. shoreae* is a root-rot fungus which attacks the living bark, cambium and sapwood. It is a facultative pathogene and an active timber rot, a potential menace to sal trees dead or alive. (Bagchee). *Trametes incerta* producing spongy brown heart-rot (gauj) works from the top of the stem downwards and its sporophores appear on the bole several feet above ground. Some of the *Fomes* are wound-parasites. Frost, drought and bad soil aeration must be regarded as precursors of attack by the species of fungi that are prevalent in the several ecological types of sal forest.

Dying-off of Tectona grandis

Die-back of the leading and lateral shoots of *Tectona grandis* is due to several causes. *Alcides ludificator*, p. 257, which tunnels for several inches down the pith of a leading shoot may kill it, but a vigorous shoot may kill the borer and the beetle will be found entombed many years after when the mature tree is felled. *Zeuzera coffeae* attack, p. 581, is primary and usually fatal. The defoliators in heavy infestations destroy the unfolding leaves and the buds so that forked tops are formed; if this destruction is repeated on a second flush from dormant or lateral buds the leader dies back. The conditions which compell larvae and grasshoppers to attack buds and gnaw the epidermis are somewhat complicated but the subsequent reaction on the part of the teak sapling, which decides whether the shoot shall die or recover, is undoubtedly dependent on its individual vigour. Death or reduced vitality is due to a collar- and root-disease; fusariosis of teak has been observed in India but has not been fully investigated. Weakness is also due to strangulation of current shoots by itonid galls, p. 435, and this is restricted to certain varieties of teak, showing up in plantations from seeds of different origin. Die back of leaders and even of the whole stem is also due to frost.

Dying-off of other species of trees:

Acacia arabica, *A. catechu* and *A.* spp.: Infection by the wound-parasite, *Fomes badius*, may be previous to or subsequent to attack by *Celosterna scabrator*.

Dalbergia latifolia: Xylotrechus subscutellatus is an indicator of disease due to a frost-canker parasite (Valsaceae) or to *Fusarium*.

Gmelina arborea. Twig-blight and die-back due to a species of Valsaceae are associated with the attacks of *Alcides gmelinae* and *Tingis beesoni* and *Loranthus*.

Heritiera fomes: Crossotarsus squamulatus and other platypodids are indicators of a root- and collar-disease (*Polyporus rhodophaeus* or *Fomes rimosus*).

Pterocarpus marsupium: X subscutellatus and *Pterolophia occidentalis* are indicators of a canker-disease due to an ascomycete.

Santalum album: The dominant spike disease is transmitted by insects; some species of hosts impart resistance and others predispose sandal to disease. Stagheadedness and thin crowns are independently due to sap-suckers. Leaf shedding or leaf-curl mosaic is due to a virus.

LITERATURE ON DISEASES AND DYING-OFF:

Bagchee K. D., 1939, *Pres Address, Botany, 26th. Ind. Sci. Congr.*, 1939, Indian forest mycology with special reference to forest pathology.

Beeson, 1934, *Ind. For.*, pp. 539-543, The role of insects in the dying-off of sal. — 1938, *Ind. For Rec.*, Ent., IV, No. 1, Guide to the insects of Dalbergia sissoo.

Champion H. G., 1922, *Ind. For.*, pp. 168-174, pl. 7, On the death of chir poles in the Almora plantations of Kumaon. — 1932, *tit. cit.*, pp. 65-68, pl. 4, On dying off of Gmelina arborea in plantations.

Hole R. S., 1927, *Ind. For.*, p. 483, Mortality of spruce in the Jaunsar Provinces.

Bark-eating caterpillars as indicators

The bark eating caterpillar, *Indarbela quadrinotata*, p. 620,

establishes itself on numerous species of trees particularly of *Acacia*, *Cassia*, *Casuarina* and *Tectona*. It utilises dead branchlets and snags to make a shelter-tunnel from which it eats the superficial layers of bark on the adjacent stem. As *Indarbela* is entirely dependent on dead wood an abundance of bark eating caterpillars is proof of abnormal production of dead branchlets or wounds due to such causes as frost, drought, congestion, etc. Bagworms (Psychidae), termites and scale insects (Coccidae) also serve as indicators of unhealthy conditions for many species of trees.

Dying-off in nurseries

High temperature during the driest period of the year which bakes the surface soil and injures the roots, and subsequent high humidity during the rains are the two main factors leading to damping-off of seedlings in hardwood nurseries in the plains. The influx of soil-moisture at the onset of the monsoon washes down a large percentage of acid and increases the concentration of salts in the topmost layer of the soil. This is inimical to the rootlets before and after the emergence of the pathogenic fungi. In the coniferous nurseries the same factors, high temperature and excessive soil-moisture before the emergence of the pathogenes, predispose seedlings to infection.

The incidence of damping-off is also correlated with the hydrogen-ion concentration of the nursery soil. The pH value of the soil fluctuates; the range of variation is from 6·5 to 4·5 from the driest period (April) to the wettest period (August); in September acidity may increase to 3·8 and the maximum percentage of wilting occurs at this time. After September acidity steadily decreases and the hydrogen ion concentration reaches almost to normal, 6·0 to 6·3, during November when practically no wilting occurs. Pathogenic fungi causing damping off and wilt of nursery stock are various species of *Fusarium*, *Rhizoctonia*, *Corticium*, *Pythium*, *Botrytis*, etc.

Soil insects causing dying off by destruction of the roots are cockchafer grubs, p. 350, and by cutting off of the stem are cutworms, p. 644. Often the whole mortality in seed beds is erroneously assigned by foresters to cockchafers or cutworms. In the case of transplants in which dying-off may be delayed for a year or more death is undoubtedly the after-effect of bad cultural work, injuries to and desiccation of rootlets at the time of transplanting, etc.

Prevention or cure

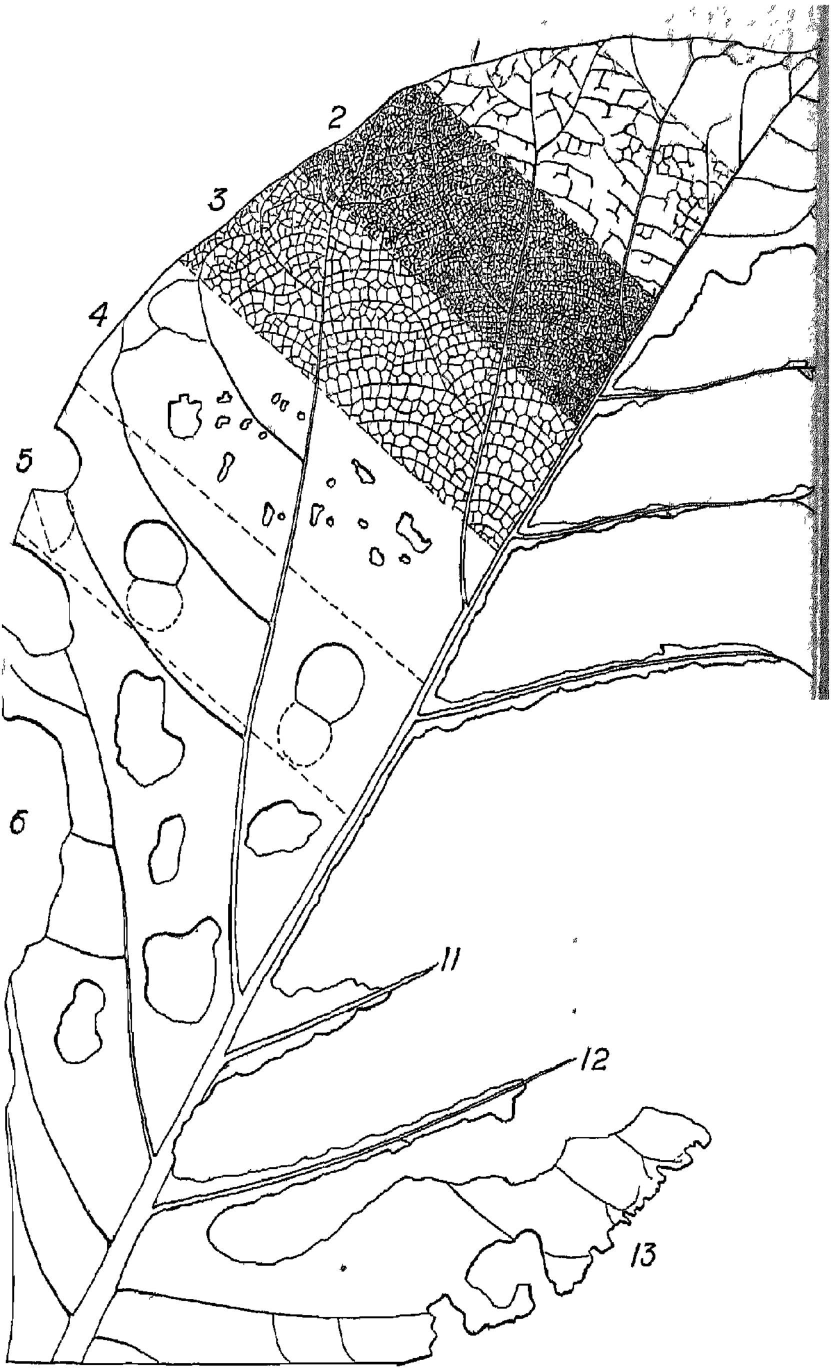
The cases that have been quoted in the preceding pages demonstrate that insects are often not the real causes of death of forest trees, but, on the contrary, are indications of a state of unhealthiness or enfeebled resistance that is primarily due to other factors in the environment. A. Howard goes still further and considers that parasitic fungi are also not the primary causes

of plant disease; their true role, in agriculture at any rate, is that of censors for pointing out the crops which are imperfectly nourished. In his opinion the policy of protecting crops from pests by means of sprays, dusts and so forth is thoroughly unscientific and radically unsound; even when successful, this procedure merely preserves material hardly worth saving. The annihilation or avoidance of a pest involves the destruction of the real problem; such methods constitute no scientific solution to the trouble but are mere evasions.

This dictum that pests attack pre-eminently those crops that are improperly nourished or are enfeebled is very widely applicable, but there are circumstances in which the reverse appears to be a truer explanation. Some species of trees of vigorous, forced growth are more susceptible to insect attack than are more slowly grown individuals; e.g., *Swietenia macrophylla* rapidly grown in the open is most heavily infested by the shoot-borer; and *Michelia champaca* of free growth in pure plantations by the champ bug; and *Tectona grandis* of which the dominants in an even-aged crop are more abundantly bored by the beehole borer, p. 573, than are individuals of smaller girth-classes. But here also it is quite logical to regard the insects as indicators of improper cultural conditions,—as censors of the forester's efforts to achieve an improvement in productivity by empirical methods. Such methods really amount to an overdraft on the biotic capital; releases of stored energy during the pioneering period often give rise to a deceptive exuberance of plant and animal life which obscures the penalties that must be paid for violent alteration in a life-community. Silviculture under these conditions becomes

Fig. 198. Feeding-patterns of teak-defoliators

No. 1—Young larvae of *Hyblaea puera* on old leaf, p. 607.
2—Young larvae of *Diacrisia obliqua*, p. 561.
3—Larvae of *Hapalia machaeralis* on mature leaf, p. 674.
4—Beetles of Chrysomelidae, p. 219, Curculionidae, p. 250 and Scarabaeidae, p. 354; also bolt-holes of young larvae of *Hyblaea puera* in heavy rain.
5—Young larvae of *Hyblaea puera* on soft leaf, p. 607.
6—Emarginations and holes by hoppers of Acridiidae, larvae of Geometridae, p. 596, beetles of Scarabaeidae; also holes by older larvae of *Hyblaea puera*.
7—Untouched leaf of *Tectona grandis*.
8,9,10—Mature larvae of *Hyblaea puera*, p. 607.
11,12—Grasshoppers of Acridiidae, pp. 713-715, mature larvae of *Diacrisia obliqua*, p. 561, *Prodenia litura*, p. 656, *Psilogramma menephron*, p. 701.
13—Emarginations by weevils of *Astycus aurovittatus*, p. 261, *Sympiezomias beesoni*, p. 293, and beetles of *Apogonia*, *Autoserica*, p. 354.



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a race between the emergence of new pests and diseases and the discovery of new technique for their control.

Control in dying-off and disease

The control principles for dying off and disease due to decreased resistance in under nourished crops, as well as for increased susceptibility to attack in over-nourished crops are the same: maintenance of a uniform soil-fertility throughout the growing-season and regulation of the ability of the soil to receive, store up and return energy. In Indian silviculture such principles must long remain academic although they offer the fundamentally correct solution. The practical remedies at the forester's disposal are those that the plant pathologist and mycologist can devise for the restriction of the activities of parasitic fungi and viroses. These remedies must depend mainly on elimination of infectious material and of alternate hosts. A further solution to the difficulty, that the forester has sometimes been forced to adopt *faute de mieux*, is to stop trying to grow the susceptible species—to cut down or abandon diseased plantations. This latter remedy is by no means modern; its forerunner can be found in a well known parable which loses none of its force if related in Urdu:—

Kisi ke anguri bag men ek anjir ka darakht laga hua tha: wuh us men phal dhundhne aya, aur na paya.

Is par us ne bagban se kaha, ki Dekh, tin baras se main is anjir ke darakht men phal dundhne ata hun, aur nahin pata; use kat dal, wuh zamin ko bhi kyun roke?

Us ne jawab men us se kaha; Ai Khudawand, is sal to aur bhi use rahne de, taki main us ke gird thaonla khodun, aur khad dalun. agar age ko phala, to khair, nahin to bad us ke kat dalna. (Luke 13).

Accurate identification (Rule ii, p. 867)

The characteristics of damage by defoliators, borers, sap suckers, etc, are not clear cut for each species of insect. Several species may produce similar types of damage to the same food plant and one species of pest may cause different kinds of damage at different stages in its life cycle. Fig 198, p 875, illustrates the variation in the feeding patterns of teak defoliators. As it is often unsatisfactory to rely on illustrations or descriptions for recognition of types of insect damage, properly named and labelled samples should be kept for reference in the divisional or range offices Instructions for the collection and despatch of specimens for identification are given at the end of this book.

SPECIFIC CONTROL MEASURES

ANOPLURA, pp. 34, 35.

BODY lice can be exterminated by disinfection and washing of clothing and bedding As a deterrent to infection use a

mixture of napthalene 96, creosote 2 and iodoform 2 parts as a powder or in an ointment. Head lice and eggs can be killed by washing the hair and scalp with a warm solution of 2 percent lysol or carbolic acid; the wet hair should be bound up in a towel or pugaree for an hour.

ANOBIIDAE, pp. 40–43.

Gastrallus birmanicus, p. 41. An outbreak in a warehouse or arsenal should be cleaned up by sterilising infested articles (e.g., ropes, coir, canes, boots, leather goods) by baking or sunheating. Susceptible material should be packed with napthalene dust.

Gastrallus indicus, The Bookworm, p. 42.

PRECAUTIONS: Extensive damage by bookworms to books in libraries, office records, files, stocks of stationery, etc., is usually evidence of long standing neglect as the damage develops and spreads slowly.

Napthalene: It should be a regular practice to keep napthalene dust (i.e., crude centrifuged napthalene or naphthalene flakes, not moth balls, p. 864) on or in the shelves, almirahs, boxes, etc. This should be renewed after it evaporates; a record room or library ought to smell of napthalene.

Bindings: The main food of the bookworm is flour paste used in the bindings of books; the paste should be poisoned at the time of binding with 10 percent solution of sodium fluoride or 4 percent solution of copper sulphate 1 part, plus arsenic pentoxide 3 parts, or a mixture of 5 gm. mercury bichloride, 60 drops creosote, 2 pints rectified spirit and 1 oz. carbolic acid. It is not necessary to treat the strawboard, cloth or leather.

REMEDIES: In a large library or record room, as a first step, locate the shelves or cupboards in which living borers are actually at work; sort out and mark those books in which the attack is old and finished so as to avoid alarm in future.

Heat: If damage is limited bake the books in an oven at a temperature of over 130°F. or expose the covers to direct heat of the sun; if the bindings and covers are too far gone rip them off and burn them and rebind.

Fumigation: Valuable material may be fumigated with one of the processes given on p. 863. The covers and backs may be swabbed with orthodichlorobenzene, or napthalene dust dissolved in petrol, or the mercury bichloride mixture given above, after trial to determine the effect on the dyes in the cloth bindings.

Lasioderma serricorne, p. 42, and **Sitodrepa panicea,** p. 43, in stored seeds, museum specimens, etc., can be dealt with on similar lines; see later under BRUCHIDAE.

BOSTRYCHIDAE

BAMBOO BORERS, LYCTUS BEETLES, POWDER-POST BEETLES, pp. 50-97.

THE protection of wood and bamboo against damage by Bostrychidae can conveniently be considered in 3 sections: (i) the Bamboo Borers or Ghoon, *Dinoderus*, (ii) the Lyctus Beetles, *Lyctus, Lyctoxylon, Minthea, Trogoxylon*, (iii) the Powder-post Beetles, *Heterobostrychus, Sinoxylon, Xylothrips*, etc. The essential difference in the two sections of wood-borers is that the beetles of (ii) lay eggs from the outside in the exposed ends of wood-vessels, whereas the beetles of (iii) bore inside the wood and lay eggs in their tunnels. Control measures common to all Bostrychidae concern methods of air-seasoning, p. 878, water-seasoning p. 879, girdling p. 878, and other processes devised to reduce the starch-content of the wood. The amount of starch present in wood can be determined by the iodine test, p. 879.

Air and water seasoning

The amount of reserve materials, including starch, sugar and fats, in the living sapwood (i.e., xylem-parenchyma and medullary rays) depends on the species of tree and the time of year at which the tree is felled. The quantity present at felling does not remain constant thereafter; the fate of the reserve materials depends on the treatment of timber after felling. Where the living cells are quickly killed by exposure, e.g., on cut surfaces, by removal of bark or by rapid drying, the starch present in the cells remains and is not altered by any subsequent seasoning treatment. Where the living cells are able to continue their activity after felling, the starch is gradually depleted and in a completely seasoned log is almost entirely converted.

Starch depletion

Depletion of the starch in sapwood can be accelerated by girdling, storage in the log, on land, or in water. The difference in properties known to exist between starches of different botanical species as well as differences in the associated enzyme systems call for caution in applying to one species of timber a depletion treatment known to be successful with another.

Girdling: Experiments have been carried out on oak in England to determine if high girdling (below the crown branches) of the standing tree due for felling reduces the starch-content of the wood below the girdle. The type of girdle is unimportant in relation to starch-depletion so long as the bark is cleanly removed from a ring about 6–8 inches wide, and a groove is cut round the middle of the exposed wood by means of a **V**- shaped chisel and mallet deep enough to ensure interruption of the longitudinal continuity of elements in the phloem and cambium. Girdling is done in early summer and the trees are felled in the winter. Trees respond very differently to this process; in some the rate

of starch-depletion in 8 months (May–January) is not sufficient and the timber remains susceptible to Lyctus attack; in others it is sufficient to prevent attack. Although 40 percent of the treated trees may be rendered immune and twice this percentage in all have a relatively low starch-content the method is not considered reliable enough for general commercial production of oak sapwood immune to Lyctus attack (Forest Products Research Laboratory, 1939).

Log storage on land: In logs stored with the bark intact for several months up to 2 years before conversion starch slowly disappears; defects due to splitting, fungal decay, etc., are reduced by keeping the logs on skids and painting the ends with creosote, gloss oil, dammar-clay, lime wash, etc., soon after felling. This method is widely adopted in temperate regions where danger from attack by bark-borers and pinhole-borers is slight. In most parts of the tropics and subtropics and for most timbers it is impracticable.

If timber is to remain in the forest for some time cross-cutting of the bole should be deferred until just before extraction of the logs. Some trees such as *Bombax malabaricum*, *Boswellia serrata*, *Dillenia pentagyna*, *Heteropanax fragrans* and *Hymenodictyon excelsum* retain the bark alive for several months and may send up epicormic shoots from logs. This continued activity of the sapwood depletes the cells of starch sufficiently to render the wood unsuitable for bostrychid attack. As soon as the epicormics and bark die the logs are liable to attack by other sapwood borers, to prevent which conversion is necessary.

Submersion in water: There is a considerable variation in the rate of resorption of starch by different species of timber. Experiments in England show that borings taken from logs which had been immersed in sea water for varying periods indicate that sea water is not favourable for starch-depletion. Starch is present in appreciable quantities in barked logs of oak, elm and ash after 5 years' immersion in sea water in a tidal basin in England. Experiments in the Andamans have not given positive evidence of starch-depletion in sea water.

The chief advantage of storing logs in fresh water is that they are protected against attack by Bostrychidae and all other borers so long as they are submerged.

Method of testing for starch in sapwood

Iodine solution: Dissolve 1 gram of potassium iodide crystals in 5 cc. clean water and add ½ gm. iodine crystals; stir well until the iodine is dissolved and then make up the solution to 100 cc. by adding 95 cc. of water. (For a larger quantity of stock solution dissolve ½ oz. potassium iodide crystals in about 1/5th of a teacupfull of water, and add ¼ oz. iodine crystals; if too much water is used the iodine will take a long time to dis-

solve. Make up to one quart which will be enough for about 250 tests).

Testing: Tests should be made on quarter-sawn faces (or obliquely radial planes) of converted timber, and then on the ends of logs. The surface tested should be planed or cut perfectly smooth with a sharp edged knife. The iodine solution is best applied as a spray by means of hand-sprayer or is shaken from a small dropping bottle (e.g., the cork pierced by a small hole); a few drops is sufficient for a few square inches; if the solution does not run it may be lightly smeared with the clean finger, and allowed to act for 3 to 5 minutes. Four tests distributed over the sapwood should be made on each piece of timber. Logs should be tested at the ends and in an L-shaped cut on the end.

Starch, if present, will appear as very dark blue streaks or specks against the yellow-stained wood. Vessels with resin or gum will show up dark brown. Seasoned or water-stored timber may show blackish discolouration, which, however, is present before staining. For practical purposes starch-content may be classed in three grades:—

(a) Nil to small starch-content. Scattered blue specks almost entirely invisible to the naked eye but just appreciable with a lens. This quantity is insufficient for the development of Lyctus.

(b) Moderate starch-content. Numerous specks and streaks visible to the naked eye but not continously distributed. This quantity renders the timber liable to attack by Lyctus.

(c) High starch-content. Surface largely or entirely stained dark blue or black and appearing grey-blue when viewed at a distance. This amount is most favourable for the development of Lyctus.

All determinations should be checked by examination with a lens, and with special care in wood discoloured during seasoning. Timber with starch-content of grades (b) and (c) is liable to damage if exposed to Lyctus attack. For practical purposes any sapwood showing a distinct bluish discoloration should be treated with a preservative.

Detection of bored wood by X-rays

The use of X-ray photography for detecting boring insects in attacked material has often been advocated. Recent work by Fisher and Tasker (1940) shows, that the presence of insect tunnels and the extent of disintegration within a sample can be detected with ease; even when not apparent from its external appearance. For the results of the examination to be conclusive the sample must not be too thick or severely disintegrated and powdered. The practical application of X-rays for the detection of wood-boring insects must be confined to timber of small dimensions, e.g., small articles of furniture, picture panels and frames, plywood, etc., and, where cost allows, could be used for determining the efficacy of methods of control by insecticide or fumigation.

The examination of structural timbers in situ in buildings for the detection of the death watch beetle and similar borers is impracticable; as such timbers are usually of large dimensions and all larvae and beetles would not necessarily be detected.

i, Dinoderus spp., The Bamboo Borers, Ghoon, pp. 53–63.

PREVENTIVE MEASURES

Time to fell bamboos: The best time to fell bamboos *(Dendrocalamus strictus)* is when the starch-content in the wood is at its lowest, i.e., during the period from the end of the monsoon to the end of December in the western United Provinces; and from the end of October to mid-January in the Punjab; in the cold season in south India; in the rains and cold season, mid-June to February in Mysore. Bamboos felled just at the end of the hot weather and beginning of the monsoon in north India are fairly free from starch, but contractors do not ordinarily work at this time of year (see also p. 59).

There is a general belief that bamboos felled during the waning of the moon are less liable to attack than those felled during the waxing of the moon, but it has been scientifically proved that the phases of the moon have absolutely no effect on the liability to attack by ghoon (p. 57).

Seasoning of bamboos: The best method of protecting bamboos during seasoning is by immersion in water, the effect of which is to leach out certain soluble substances and to change the composition of other substances on which the borers feed, p. 60; it also produces an unpleasant smell. The soaking should last for 2 to 3 months in still water or less in running water. Bamboos extracted by river in rafts are rarely attacked by borers.

Bamboos stored without water-treatment should be rubbed with crude oil at the ends, on abrasions, trimmed surfaces, etc. Stock should be inspected at least twice a year (in March and July) and attacked pieces should be removed and destroyed. If old attacked stock is allowed to accumulate it is a perpetual source of danger to new stock as the life-cycle of the borer from egg to beetle can be completed in 3 months. Bamboos which do not show more than two borer-holes per internode after being stored six months may be regarded as immune from further attack. A borer-hole may be defined as one with a depth not exceeding $\frac{1}{4}$ of an inch and producing no dust if poked with a pin.

There is practically no difference in the liability to attack of bamboos stored in the open or stored under cover. Baking or smoking bamboos for the purpose of straightening does not protect them from ghoon attack unless the temperature is high enough to char the outer skin. Rubbing bamboos with linseed, mustard or other vegetable oils does not protect them permanently unless frequently repeated.

Purchase from contractors: The purchaser should

obtain a guarantee that the bamboos have been (a) felled between October and January, or (b) seasoned in water or rafted for 8 to 12 weeks, or (c) seasoned on land for six months. If bamboos are purchased unseasoned or green the manufacturer or consumer must either store them for the required quarantine period or must treat them with preservatives.

Split bamboos used for matting, chicks, basketwork, trays, etc., are best converted green to the required dimensions and then soaked in water until leaching out is complete.

Preservative treatment: Water-soluble preservatives are unsuitable for partly seasoned bamboos as splits develop in the subsequent quick drying. Treatment in hot oil causes cracks; and in tent-poles the fittings get loose owing to shrinkage

Adequate immunity from borer-attack is obtained by soaking in a 50 : 50 mixture of cold creosote and heavy fuel oil for 48 hours. If tank-capacity or time is limited an accelerated output is obtainable by drilling holes in a hollow bamboo, either (a) two $\frac{1}{4}$ inch holes through the wall of each internode placed at opposite ends and opposite sides, or (b) from end to end through all the nodal partitions. For the first a $\frac{1}{4}$-inch bowstring or twist-drill is used; for the second a $\frac{1}{2}$-inch augur brazed to a flexible cast iron rod 10–12 feet long with a cross handle at the end, the bamboo being clamped in a vice. These perforations do not appreciably reduce the strength of the pole. The period of immersion for drilled bamboos in cold 50 : 50 creosote-fuel oil may be reduced to 2 hours and still produce temporarily serviceable poles; 4 hours gives better absorption and distribution of the preservative, which penetrates through the fibro-vascular bundles where cut transversely and through the internal parenchyma, from the inner wall; there is no penetration through the outer uncracked wall. A period of 2 hours drainage at the tank-side, preferably in a vertical position, is needed after immersion and before drying off.

In the absence of a tank, hollow bamboos can be treated on a small scale by drilling and upending vertically and filling each internode (or the whole cavity) with oil through the holes, leaving for 2 or 3 days and then reversing until completely drained.

T e n t - p o l e s , l a t h i s , e t c . : For tent-poles supplied by contractors with the metal fittings ready fixed the internodal drilling process (a) can be done after the fittings are in place. This process is suitable for army tent poles when the oil treatment is done in arsenals after purchase of the completely fitted article. The nodal drilling process (b) is suitable for tent-manufacturers who cut and fit their own poles. Nodal drilling must be done first and the preservative treatment and drainage must be done before the fittings are added.

Solid bamboos and lathis which cannot be drilled by either method should be immersed for 48 hours in creosote-fuel oil for

satisfactory absorption; or overnight (say 16 hours) at the minimum for moderate serviceability.

In tent and telephone poles, lathis, etc., which are to be oiled immediately after receipt, borer-holes to a maximum of 10 holes per internode may be allowed without affecting the strength. The presence of borer-holes ensures better penetration by the preservative. (Note that if no treatment is adopted, the maximum permissible number of holes per internode is two).

If treated bamboos are cross-cut, shaved, drilled or otherwise reshap-d the exposed places should be swabbed with earth oil or creosote, before the fittings are fixed.

REMEDIAL MEASURES

Attacked bamboos in which the boring is not too far advanced can be saved by the preservative treatments described above.

Bamboo or cane furniture, chicks, baskets, etc., are best treated with kerosene, and, if available, ortho-dichlorobenzene (p. 884).

ii, Lyctus, Lyctoxylon, Minthea, Trogoxylon, The Lyctus Beetles, pp. 67–83, 94.

Although Lyctus beetles are indigenous in forests and timber depots they are primarily pests of mills and factories making wooden articles. Infestation very rarely starts in the log while the bark is intact.

PREVENTIVE MEASURES

These comprise the general measures for seasoning and cleanliness in the mill premises and the special measures needed for the kind of product manufactured.

Seasoning and **Starch depletion,** see pp. 878, 879.

Mill hygiene: The most important measure is regular inspection of all stock, i.e., unused timber, manufactured articles, waste material, rejections, stocks of wood for fuel or subsidiary purposes. In north India twice a year, in south India more frequently, during the warmer seasons, inspections should be made to discover and destroy attacked pieces before the beetles escape; whenever stacks are dismantled or unconverted timber is sawn similar inspections and rejections should be made. Offcuts and sawing refuse are particularly dangerous and may continue to breed beetles for years if accumulated. A mill manager should always know whether Lyctus is breeding on the premises or is being introduced in timber from outside sources. Classify stock into sapwood (susceptible) and heartwood (immune) and pile it separately. Arrange to use up old stock progressively before the new. Use only heartwood sticks or cleats for piling sawn timber.

Treatment with preservatives

Whether impregnation or steeping or short periods of immersion in a preservative can be adopted commercially, depends largely on the kind of product and its value. Water-soluble preservatives when impregnated at the lethal concentration do not always

prevent oviposition by Lyctus beetles but the larvae that hatch out do not do any significant damage before dying. Oil and solvent preservatives give effective protection.

Oils

Where discoloration of the wood does not matter some oils can be used effectively.

Creosote: Immersion in a mixture of creosote 1 part and kerosene 2 parts for 5 minutes remains effective for at least a year. If the proportion of creosote is reduced the mixture is less effective; a reduction to one part creosote in 8 parts kerosene is necessary to eliminate the stain and this mixture is ineffective. A mixture of 1 part creosote and 3 or 4 parts crude oil (used against large powder-post beetles) is effective also against Lyctus.

Orthodichlorobenzene: Immersion for 10 seconds in the cold undiluted liquid is effective. It does not leave a permanent stain. A cheaper mixture is equal parts of orthodichlorobenzene and kerosene or turpentine; this has an equally good or better penetrative power in a quick dip. Kerosene and turpentine alone are not permanently effective.

Water-soluble preservatives

The effectiveness of water-soluble preservatives varies very considerably with the composition and temperature of salt solution, the period of immersion, the species of timber, and the species of borer. The most important factor is the depth of penetration obtained by immersion; the preservative must be present at lethal concentration at a depth equivalent to that to which the *Lyctus* egg is inserted and the newly hatched larva starts to bore. For *L. brunneus* the depth would be 6 or 7 mm., for *L. africanus* less. Water-soluble preservatives tested at Princes Risborough (Cann, 1940) were found to be effective against *L brunneus* only when applied by an impregnation treatment. Immersion of air-dry wood in cold solutions of borax, potassium chromate, sodium fluoride, sodium fluosilicate, and zinc chloride at strengths as high as 5 percent and for periods as long as 5 minutes is ineffective. Moreover, neither heating the wood for half an hour immediately before immersion, or the addition of a wetting agent to the preservative solution increases the penetration sufficiently to make the treatment effective. Whereas concentrations of as low as 0·1 to 3·0 percent of the toxic substance are lethal to *Lyctus* if obtained by impregnation, a superficial concentration of 5 percent is inoperative. On the other hand, some water-soluble preservatives tested in the U.S.A. in the form of '10 second' dips in 5 percent solutions held at 130° F. or higher proved effective against *Lyctus parallellopipedus* and *L. planicollis*.

Borax and **boric acid:** A '10 second' dip in a 5 percent solution held at a temperature of 130°F. gives effective penetration

and protection against *Lyctus parallelopipedus*; deeper penetration is obtained by raising the temperature of the solution to 190° F., which gives more effective protection against the larger *L planicollis*. The borax dip is also effective against sapstain in hardwoods. It is regularly used by U. S. A. lumber companies for the treatment of newly sawn hardwoods (Christian, 1939).

Immersion in a cold 5 percent solution for 5 minutes of green unseasoned timber and of timber dried at 130°F. for 30 minutes, with and without wetting agents, were ineffective under test at Princes Risborough. Immersion in a 1·25 percent solution held at a temperature of 200°—212°F. for periods of 10–40 minutes is effective for the protection of green veneers of Australian timbers.

The apparent lethal concentrations, as a percentage of the air-dry wood, are about 0·12 percent for boric acid, 0·2 percent for a mixture of 2 parts boric acid plus 1 part borax, 0·11 percent for a mixture of equal parts of boric acid and borax, and 0·2 percent for borax alone. Although there is little practical difference between the toxicity of boric acid, borax, or mixtures of the two, there is less liklihood of discoloration of the treated wood with boric acid and it is consequently to be preferred to borax (Cummins, 1939).

Boric acid treatment of veneers

Plant: For the treatment of veneers by submersion in a hot solution of boric acid a copper tank is needed. Iron tanks are unsuitable because of the presence of tannin and organic acids in most timbers and the slight acidity of the antiseptic solution. The acid dissolves the iron which reacts with the tannin and produces a black coloration which spoils the appearance of the wood.

The treating tank should be of copper with brazed joints fitted into a wooden supporting framework or box and heated by means of a steam coil. For treatment of full-sized veneers a tank 9′×4½′×4½′ may be required. The veneers or battens or shooks to be treated are packed into a wooden crate designed to take the particular dimensions of the material. Each piece of material is kept from coming into contact with its neighbours by means of separators or spreaders of copper or hard wood. The crate is nailed or screwed with copper. It is lowered into the tank and prevented from floating by adding weight. Designs and specifications for a treatment tank and crate are given in Reprint No. 56 from the *Journ. Counc. Sci. and Indust. Res., Australia*, 1939, 12, pp. 30–49, figs. 1–3. The preservation of timber against the attacks of the powder-post beetle (*Lyctus brunneus* Steph.) by impregnation with boric acid.

Process: The antiseptic solution is maintained at a temperature of 200°F. to boiling point 212°F. The strength of the solution is 1·25 percent boric acid and must be kept up to normal by adding at requisite intervals extra chemicals to compensate for that absorbed by the wood and extra water to compensate for loss by evaporation and absorption. It is necessary to work out a schedule for maintenance of solution strength

according to the size of the tank, formula used, species of timber and dimensions of treated material and to check up at intervals by analysis of samples of the solution. The time required for complete impregnation of the material varies with its dimensions: 10–40 minutes is sufficient for veneers of 1/20th upto 3/16ths of an inch thick: longer time is needed for box-shooks, bamboos, etc. Details of treating schedules for veneers are given in the *Journal* of the C. S. I. R. quoted above.

Veneers should be treated at once after peeling while still moist. In thicknesses greater than 3/16ths of an inch the process is uneconomical for sapwood veneer owing to the time of treatment required. It is preferable to treat susceptible sapwood in thin veneers and to cut thicker veneers from non susceptible heartwood. Treated veneers can be satisfactorily glued with a casein glue. The colour of the wood and its subsequent finishing are not affected (see also p. 893).

The boric acid process is patented. For permission to use the process application should be made to the Chie , Division of Forest Products, 69 Yarra Bank Road, South Melbourne, Australia.

Sodium fluoride: A 0·1 percent impregnation (0·0375 lbs. of salt per cuft. of wood) is effective against *Lyctus brunneus*.

Sodium fluosilicate (silicofluoride): This salt, Na_2SiF_6, is the most toxic of the chemicals ordinarily prescribed for *Lyctus* control: a concentration of 0·06 percent (0·024 lb. of dry salt per cuft. of wood) is lethal. A '10 second dip' in 5 percent solution is effective (see p. 865).

Sodium pentasulphide; or in a liquid form under the trade name sulfocide, is effective in a 5 percent solution and a '10 second' dip or at 1 percent and 190° F.; the treatment is comparatively expensive.

Zinc chloride: For small dimension material (e.g., 1/2" to 1" cross-section battens for tea-chests) a 6 percent solution has been used successfully in India against *Lyctus* and *Minthea* by the hot and cold tank method, viz., after air-drying in open stacks for a few days, 1 hour in the hot bath and then immediately transferred to the cold bath for 2 hours and then drained, and then dried off in a hot air drying chamber. A 4 percent solution of zinc chloride with 2 hours in the hot bath and 4 hours in the cold bath is advisable for timbers which are weakened by the stronger solution of preservative. The effective concentration is a 3 percent impregnation (1·25 lb. salt per cuft. of wood); in some Australian timbers as low as 0·8 percent (0·1 lb. per cuft.) is effective.

Solvents

Chlorinated napthalene wax: Immersion in a 20 percent solution of Seekay wax (R 93) in benzene for 5 minutes giving an absorption of 0·006 to 0·017 gm. per c.c. wood, is effective (Cann, 1940).

Pentachlor-phenol: *Lyctus*-free air-dried material can be

effectively protected against infestation by means of a '10 second' immersion in a solution of 2 percent pentachlorphenol and 98 percent light fuel oil (with a B.P. around and slightly above that of kerosene). *Lyctus* infested material up to 4″ × 4″ section can be sterilised by immersion for 5 minutes in a solution of 3 percent pentachlorphenol in 97 percent light fuel oil. This treatment is used by U.S.A. manufacturers of door and window frames; the wood is not discoloured and can be painted (Christian, 1937).

Brushing

Oils: Low temperature tar phenols brushed on the surface in a single treatment are effective deterrents for at least a year after treatment (Cann, 1940). Low temperature phenols distill between 170° and 239° C.

Solvents: Those solvent preservatives that are effective when applied by means of a rapid dip are also effective if brushed on in an even and complete coating.

Varnish: Another class of agents which can be used under special conditions are the varnishes or fillers which prevent oviposition by their ability to fill up the pores and open wood-vessels. According to its quality and finish the varnish is used for covering exposed surfaces (tangential or radial faces) or the cross-cut edges and fibrous surfaces, or the portions of treated wood exposed by subsequent sawing and trimming:—

Gloss oil: Hardened gloss oil is made of 100 parts by weight of rosin, 8 of quicklime and 57·5 of a thinner such as mineral spirit. Filled hardened gloss oil is made by mixing 25 parts by weight of fibrous talc, 25 of barytes and 100 of hardened gloss oil; the purpose of the inert pigments is to increase the moisture-resistance. One gallon covers an area of about 150 sq. feet applied cold with a paint brush.

Lac: Lac or shellac dissolved in spirit is the basis of various varnishes and polishes. The cheapest varnish is formed from kiri or refuse lac (the price of which may fall as low as Rs. 4 a maund); it can be subsituted for sodium silicate on plywood.

Linseed oil: Boiled linseed oil may be painted on hot and followed by a second coat after the first has dried. The boiled oil will dry more rapidly than the raw oil especially if kerosene is added to the hot oil. Linseed oil produces a slight yellow stain. It can be used on unseasoned wood.

Resin-kerosene: Where crude resin is available at cheaper rates than rosin a mixture of resin and kerosene oil makes a fluid slow-drying filler that is well absorbed and is useful for protection of rough material awaiting carpentry or turnery.

Sodium silicate: Crude sodium silicate (water-glass) is an excellent filler for coarse-pored woods and especially for plywood panels. The cheaper grades of sodium silicate are more fluid

and require less dilution than refined grades. It is applied cold with a stiff broad brush to the edges or transversely sawn faces; it stains the wood dark. If panels of plywood or battens or shooks, that are to be held in stock at the factory, are stacked truly with a clean vertical alignment in solid blocks or walls the staining does not penetrate to the inner or veneer faces near the edges. The same treatment can be applied to lots of panels packed immediately after pressing and drying for despatch to consumers; the varnishing should be done before the metal-strapping or cross battens are fixed. As an additional precaution the top and bottom faces of the package may be covered with paper, or a varnished sheet of single veneer whichever is more convenient. Panels so packed can be issued under a guarantee of borer-free and will remain unattacked so long as the package is unbroken (see also p. 893).

REMEDIAL MEASURES

Kiln sterilisation

Experience in the United States and in England has shown that moist heat can be used to destroy borers in timber. Temperatures of 130° F. and above, maintained for $1\frac{1}{2}$ hours, after the internal temperature of the timber in the kiln has reached 130° F., at 100 percent humidity are fatal to *Lyctus* larvae and beetles. As there is a variable lag between the temperature of the interior of the timber and that of the atmosphere of the kiln, it is necessary to lengthen the time of treatment accordingly.

1. Raise the temperature of the kiln, after loading with infested timber, to 130° F. so that this temperature occurs throughout the kiln (coolest part of kiln, outlet end, should record 130° F.).

2. Hold the kiln temperature at 130° F. for a period that should be varied with the thickness of the timber, type of kiln, etc., to ensure that the required temperature is attained throughout the timber. This period will vary from $\frac{1}{2}$ an hour for 1-inch thick timber to $4\frac{1}{2}$ hours for 3 inch stock, and should be determined by th e kiln operator.

3. Commence the lethal treatment by blowing in live steam and maintaining the atmosphere of the kiln at saturation point, 100 percent, and the temperature at 130°F., for $1\frac{1}{2}$ to 2 hours.

Further details will be found in Forest Products Research, Leaflet No. 13. The kiln sterilisation of Lyctus infested timber, 1937 (Princes Risborough, England).

The actual lethal temperature for *Lyctus* is less than 130°F., and sterilisation can be obtained by using lower temperatures and lower humidities for longer periods than those noted above. Thus at a temperature of 125°F. with humidities of 60 to 80 percent maintained for 4–2 hours, or, temperature of 115°F. with humidities of 60 to 80 percent for 36-30 hours, or temperature of 105° F. with humidities of 60 to 80 percent for 170–164 hours produce

fatal conditions in timber one inch or less in thickness. It should be possible to devise schedules for kiln sterilisation of Lyctus infested timber that can be followed in most kilns in commercial use, provided the maximum temperature and maximum relative humidity attainable are known. The total period of exposure, reckoned from the time the atmosphere of the loaded kiln reaches the required temperature and humidity is the sum of the lethal period, the lag period and the safety factor.

Heat-sterilisation of timber and kiln-drying may ordinarily be carried out together by a combined process involving only one handling of the timber. If timber is kiln-dried either green from the saw or after being partially air-seasoned, the normal kiln-operating conditions will be severe enough to destroy Lyctus infestation and no special sterilisation treatment is necessary. It is advisable to sterilise or kiln-dry timber just prior to manufacture or export.

Kiln sterilisation can be used for glued joints, laminated wood and plywood in which moisture-resistant glues are used (synthetic resin, good quality casein or blood albumen glues). Scotch glue or poor quality casein will stand only the mildest treatment.

Logs in the round which are attacked by Lyctus can be efficiently sterilised by treating them in steam chambers heated with exhaust or other steam-supply for 3-6 hours according to the thickness of the sapwood or of the infested zone.

While heat-sterilisation destroys all Lyctus present in the treated timber it neither prevents initial attack or renders it immune from further attack. But if combined with a system of regular inspection of stocks and segregation of infested material it provides an effective means of preventing increase and spread (p. 883). Sterilised stock that is exposed to future infestation from sources beyond the control of the mill owner should be treated with insecticides or fillers (pp. 884–887).

Chemical sterilisation

Finished wood products which reveal active Lyctus damage after being taken into use, e.g., furniture, wood-work in houses, can be sterilised by painting or injecting petrol, kerosene, orthodichlorobenzene, p. 884, or mixtures of the same; the object is to get complete penetration into the larval tunnels through the holes from which dust is ejected; a small syringe or squirt is useful.

LITERATURE ON THE CONTROL OF LYCTUS ATTACK:

Browne F. G., 1938, *Malayan For.*, VII, pp. 118-119, The common Malayan powder post beetle.

Cann F. R., 1940, *Forestry*, XIV, pp. 27-37, Experiments in Great Britain with wood preservatives for the prevention of Lyctus attack. — 1941, *Forestry Abstracts*, II, pp. 177-179, Recent work on the prevention of Lyctus attack by chemical methods.

Christian M. B., 1939, *Southern Lumberman*, Dec. 15th 1939, pp. 105-109, figs.

Cummins J. E., 1939, *Journ. Counc. Sci. Ind. Res*, *Australia*, XII, No. 1, pp. 30-49, The preservation of timber against the attacks of the powder

post borer (Lyctus brunneus Stephens) by impregnation with boric acid (Reprint No. 56).
Cummins J. E. and Wilson H. B., 1936, *tit. cit*, IX, pp. 37. The preservation of timber against the attacks of the powder post borer (Lyctus brunneus Stephens) by impregnation with various chemicals
Garthwaite P. F., 1940, A guide to the borers of commercial timbers in Burma, pp. 7-9, pls. vi, vii
Parkin E. A., 1937, *Forestry*, XI, The kiln sterilization of timber infested with Lyctus powder-post beetles.

iii, Heterobostrychus, Sinoxylon, Xylodectes, Xylothrips, etc.,

The Powder-post Beetles, pp. 64–67, 85–97.

Control measures are practically the same for all these genera but differ according to the type of wood, e.g., ballies and poles, logs, sawn timber, p. 891, plywood, p. 892.

PREVENTIVE MEASURES

Ballies, poles and logs.

As ballies, posts, and poles of small girth are wholly or largely sapwood they are liable to almost complete disintegration into wood-dust if severely attacked. It must be decided whether permanent or temporary protection is required; the cost of permanent protection is relatively high for the value of a pole.

Permanent protection: Impregnation: To protect a pole permanently against attack by powder-post beetles and wood-destroying fungi impregnation of the wood is essential. Complete impregnation is best obtained by pressure processes in a cylinder large enough to take a full length pole; preservative oils or water soluble preservatives are used according to the normal treating processes for the preservation of seasoned wood. But it is not necessary to treat the heartwood of many species of trees as powder-post beetles do not penetrate it. The sapwood of almost all Indian timbers and the heartwood of susceptible softwoods can be treated efficiently by the open tank process which requires immersion in the hot preservative followed by cooling in a cold bath of the same. Both the pressure and open tank processes require the wood to be well seasoned beforehand to secure the best results, and it is during this period of seasoning that the attacks of powder-post beetles are liable to start. Consequently their use is limited to material derived from early winter fellings or accelerated seasoning.

Seasoning: Poles which are seasoned to practically air dryness in the sapwood are not thereafter attacked by powder-post beetles; if a stray beetle should bore in, it abandons the attempt after entering a third of an inch or so. (This 'attack' should not be confused with larval boring which starts in moist wood and continues after it has dried). Rapid drying should be arranged so that the pole is exposed for as little as possible to borers during the period of seasoning by (a) prompt removal from the coupe where there is felling-refuse, (b) barking, and (c) storage

in a depot in the sun in open rows, one end raised from the ground ('vertical stacking' or 'end-racking'), or (d) storage in the sun on the ground and rolled over at short intervals, or (e) kiln-seasoning. After the poles are thoroughly dried out they may be concentrated in stacks or piles without danger.

Logs: Methods (a)-(d) above give some measure of protection to logs, but if the sapwood is to be fully utilised rapid conversion is advisable.

Temporary protection in forest timber depots: Dipping: When impregnation or rapid seasoning cannot be arranged the green poles can be given temporary protection by removal of the bark and dipping in a tank containing the cold preservative. The object of this dipping is to coat the surface of the pole with a layer of oil which will prevent the access of beetles by means of its oiliness and smell during the period the pole is seasoning. It is necessary to renew the treatment as soon as the oil has lost its deterrent properties through evaporation or weathering. Except in very humid climates or during monsoon seasons the single dip carries the poles through the critical period of seasoning. When cheapness is the first consideration a fuel oil or crude oil can be used provided it is not too viscous for ease in operation; crude oil can be diluted and thinned with the more expensive creosote in the proportion of 1 of oil to 4 of creosote up to equal parts of each. The best procedure uses two tanks loaded and emptied alternately, each operation taking about 10 minutes if the tank is small and giving an average immersion period of 10 minutes per pole; after dipping the treated poles are kept on a drainage-platform during the period the next load is being immersed; they can then be close stacked. If the tanks are heated better absorption is obtained and the protective effect lasts longer (p. 863).

REMEDIAL MEASURES. Sterilisation after attack:

Cold water: Poles and logs already infested with bostrychid borers can be sterilised by submersion in cold water; 80–100 percent of the borers in the larval and imaginal stages are killed by one week's immersion; longer periods of immersion up to 40 days do not increase the minimum mortality proportionately. The extent of penetration of water along the tunnels of the borer depends on the severity of the attack, being more extensive where there are more holes.

Hot water: Immersion of poles and logs in hot water will kill bostrychid borers in the sapwood to an extent depending on the temperature of the water, the period of immersion and the thickness of the sapwood; 100 percent kill is obtained, e.g., at 135°F. for $\frac{1}{4}$ inch sapwood in $\frac{1}{2}$ hr., $\frac{3}{4}''$ 1 hr., $1\frac{1}{4}''$ $1\frac{1}{2}$ hr.; at 200° F. for 1″ 1 min., $1\frac{3}{4}''$ 5 min., 3″ 10 min.

Sawn timber

PREVENTIVE MEASURES. Planks and scantlings should

undergo a short period of air-drying straight from the saw bench by exposure to the sun in open vertical racks, followed by immersion in a tank of creosote-oil as described under 'Temporary protection' above. From the tank the material is stacked wet in the permanent piles, usually in sheds. This treatment is also effective against oviposition by Lyctus beetles; it does not stop the further development of bostrychid larvae already in the wood before dipping.

Heterobostrychus, Xylothrips, etc., in factories

Logs: The most effective means of protecting logs lies in early extraction and conversion. In the case of trees felled between November and April the liability to attack in the forest is relatively small. Those felled at the end of the hot weather and during the rains are most likely to be attacked; they should be extracted and converted with as little delay as possible, with the exception that logs extracted by floating are safe so long as they are submerged in water.

Inspection: It should be possible to keep sawmills, factories or storage depots in any locality practically free from borers by frequent inspection of stock and by burning or disposal of infested pieces. One regular inspection a year of the whole stock preferably during the cold weather, is the least that is advisable. Two inspections in March and in October are desirable. When this is done it is evident that no production of borers can take place on the mill or factory premises, because the life-cycle of the pest takes one year; the external sources of danger are counteracted by the same preventive measure, because infested material is not given a chance to produce mature beetles. The very small proportion of stock that may have to be destroyed by this practice represents a loss much less than the expenditure entailed by treatment with antiseptics. Under very bad conditions an additional precaution would be given by distributing freshly cut waste of semul or mango or other softwood in the dimensioned stock godowns from May to September to act as baits or traps to stray beetles, and burning these pieces in December. If these baits show signs of heavy infestation (holes and dust) it means that stricter supervision and inspection is needed.

Stacking: Stock of small dimensions such as plywood panels, battens and fittings for teachests, shooks and caseboards, etc., stored in godowns should be stacked in piles one piece thick so that the opposite sides of the stack can be inspected. The removal of attacked pieces from closely stacked material is facilitated if open shelf-racks are installed with shelves at a few feet apart vertically.

Plywood and veneers

Plywood: Plywood made up from infested logs is automatically sterilised during the processes of peeling and glueing; hence

damage does not carry over from the log to the panel. Protection is obtainable by the boric acid treatment, p. 885. Untreated plywood panels that are completed in November and onwards are not liable to damage until the following rains in north India. Such material can leave the factory with a guarantee of being free from infestation by *Heterobostrychus Xylothrips* and *Stromatium*. Panels that must be held in stock for longer than six months or throughout the rains can be protected (if damage is expected) by varnishing as described on p. 888, or by strapping up in units comprising sufficient panels to form a cube, boxed in by panels on all sides; these cubes should be stacked with narrow battens between each in the vertical tiers. Panels-made wholly of heartwood are immune. Casein lime glues for plywood usually contain an antiseptic such as copper chloride, sodium fluoride, or sodium arsenate to increase their working life. These salts are slightly toxic to borer larvae but are not present in quantities sufficient to check the passage of larvae from one veneer to the next. Phenol formaldehyde resin binders are impervious to fungi and termites and bostrychid borers.

Veneers & splints for matches: Matchbox veneers are attacked after they are cut to shape, stamped, edges painted and stacked, and the damage may develop seriously if the stacks are left undisturbed for several months. The simplest precaution is a methodical system of stacking and consumption so that the oldest stocks are used up first, damaged material of all kinds is removed and destroyed and reserve stocks are protected against oviposition. A bad infestation usually means that extensive breeding is taking place in the rejections and waste from lathes and saw-benches, and that a thorough inspection of the mill premises is needed. While the clean up is in progress it is advisable to protect the current output of veneers by storing them in separate packages either enclosed in paper or boxed in by sheets of veneers sealed at the edges. If the danger is chronic the only alternative is antiseptic treatment of veneers by dipping in boric acid, p. 885, or zinc chloride, p. 886, or spraying completed stacks with strong solutions of the same.

Damage to filled matchboxes in packing-cases held as reserve or in bond usually originates from the box-shooks; either attacked shooks have been used or the cases have remained undisturbed long enough for a generation of the borer to be completed. Shooks should be treated with a preservative before making up into cases.

Rhizopertha dominica, p. 83.

Is a pest of pith topis ovipositing in the shapes during manufacture, feeding on the paste and emerging later from the finished article, making holes in the cloth cover. Topis supplied by contractors to the army are completely protected by the addition of 2 parts of powdered copper sulphate to 100 parts flour used for paste. Full protection is also obtainable by more expensive

poisons, i.e., sodium fluosilicate, 10 percent solution in water, or copper-sulphate 1 part, arsenic pentoxide 3 parts by weight in 4 percent solution in water.

Sinoxylon attack on living trees, pp. 87–90, 93.

When beetles of *Sinoxylon* spp. bore into the stems of saplings and the trunks of poles or branches of the crowns of trees, it is usually because excessive breeding of borers is occurring in felling-refuse or fuel stacks in the neighbourhood. The reaction of the tree is death, dying-back, exudation of resin or gummy sap, stagheadedness, etc., according to its powers of resistance, see pp. 816. The remedy is a clean-up of the breeding-material near the site of attack.

BRUCHIDAE, Pulse Beetles, Seed Weevils, p. 108.

Storage of seeds

After collecting and cleaning, dry the seeds in the sun. If it is suspected that they are already attacked by seed weevils (which can be ascertained by careful examination for holes or discolouration, etc.) fumigate the whole material before transfer to the storage-receptacles. Drying alone will not prevent the continued development of borers unless the *moisture-content* of the infested seeds is reduced below 8 percent; moisture-contents of 15 to 20 percent are very favourable for the existence of grain weevils.

Fumigation: Carbon disulphide: see p. 863. The dosage required is 32 oz. per 1,000 cuft., and if a small fumigating chamber is used it is advisable to double the dose. For wheat, etc., the dose is proportionate to the weight of grain and not to the space in which the latter is kept; from 1–1½ lb. per ton of grain in airtight bins or chambers, and 2 lbs per ton, in more open bins.

The carbon disulphide is poured into a shallow vessel and allowed to evaporate. Fire should not be brought near it as it is inflammable. Grains should be exposed to this treatment for only 36 hours. For large stocks in rooms the material is poured in small saucers and put in a few places and in a saucer on the top of the heap of the grain. The gas is heavier than air and falls into the grain. The room should be closed and made airtight. There is, however, great loss of gas by leakage and absorption in an ordinary white-washed and plastered room.

Hydrocyanic acid gas: p. 863. The dose for 1,000 cuft. is 10 oz. of 98 percent grade potassium cyanide in 10 oz. sulphuric acid diluted with 30 oz. water. Both of these ingredients are poisonous and dangerous. When expert handling cannot be guaranteed it is better to use calcium carbide, which produces acetylene gas on addition of water.

Storage: The most effective kind of receptacle has a large wide base and a narrowed top. There should be a small opening near the base large enough for the hand to enter. In many

country districts storage bins or baskets are made of split bamboo, cane, plaited straw, etc., plastered with cowdung mud; the opening at the bottom is closed within by means of half a coconut shell, or an earthenware saucer, or tin lid, kept in place by the pressure of the seeds. The upper surface of the seeds, after the bin has been filled is covered with a layer of sand 2 inches deep, or a mixture of sand and chunam (powdered lime), or the ground powder of the root and bark of *Mundulea suberosa*. The object of the sand-layer on the surface is in case infested seeds are stored. Bruchid beetles on maturing climb up to the surface before pairing and they are unable to get back again to lay eggs in the sound seeds below. It also facilitates the removal of seeds in small quantities from time to time through the opening at the base of the bin; if the layer of sand is much disturbed by settlement renew it and respread it on a layer of cloth or paper. The use of *Mundulea suberosa* powder instead of sand is desirable in case of food grains and pulses, etc., or if the lids of the storage bins are defective and allow beetles to escape.

Dusts: Seeds which are stored in small containers can be protected by mixing with dusts, viz., dry wood ash, calcium carbonate or precipitated chalk, slaked lime, china clay, etc. The proportions are about 1 percent for chalk to 5 percent for slaked lime. This treatment prevents oviposition; it does not stop the development of weevils inside seeds already infested.

Mercury amalgam: Seeds or food-grains (such as wheat, rice, maize, pulses) that are liable to damage by *Calandra oryzae*, p. 262, *Rhizopertha dominica*, p. 83, and *Bruchus* spp., p. 109, are protected for long periods by storage in air-tight receptacles in which is also placed an amalgam of mercury. The merits of the method are controversial, some claiming it is perfectly satisfactory, others repudiating its alleged usefulness. Two parts of tin and three parts of mercury are pounded together in a mortar until a homogeneous paste-like amalgam is formed, which is strained by squeezing through cotton cloth to remove excess of mercury and flattened into broad thin discs. About half an ounce of amalgam is required in a kerosene tinfull of seeds; the amalgam can be used over and over again; the mercury vapour is believed to kill eggs laid by beetles that may be present.

LITERATURE ON CONTROL OF STORED SEED PESTS:

Fletcher T. B., 1918, *Agric. Journ Ind.*, XIII, p. 527, The protection of wheat from weevils.

Kunhikannan K., 1919, *Mysore Agric. Calendar*, pp 13, 16, 17, figs. 2, Pulse beetles in the store. — 1919, *Mysore Dept. Agric.*, Ent. Ser., Bull. No. 6, pp. 31, figs. 18, Pulse beetles.

Anon, 1940, The storage of foodstuffs in the Colonial Empire (A memorandum prepared by the Agricultural Advisers to the Secretary of State for the Colonies) in *Trop. Agr.*, XCV, pp. 29-48; and *Bull. Imp. Inst.*, XXXVIII, pp. 163-180. — 1940, *Ind. Farming*, I, p. 35.

BUPRESTIDAE, pp. 110–119.

Sapwood borers of felled timber

OVIPOSITION by practically all species of Buprestidae is prevented by removing the bark from logs shortly after felling. Remedies for *Buprestis geometrica*, p. 115, and similar species are as for Bostrychidae, p. 891.

Buprestidae attacking living trees

Leaf-miners, twig-girdlers and bark-borers: No control measures have been worked out for any species of these groups attacking living trees in India. Remedies used elsewhere are direct and intended for shade and fruit trees, e.g., opening up larval tunnels and injecting a fumigant, p. 863, or spraying the bark with a repellent such as Bordeaux mixture, p. 859, or lime-sulphur or whitewash; see also under *Xystrocera*, Cerambycidae.

Defoliators and decorticators: Abundance of beetles of *Psiloptera* and *Sternocera*, pp. 117–119, feeding on the leaflets and stripping the bark of twigs of leguminous trees probably follows excessive breeding in stumps and roots of felled trees. The correct control measure is disposal of the abnormal quantity of breeding-material by barking or uprooting the stumps or by earthing them over so that termites are attracted. Nursery stock or transplants can be protected by spraying with lead arsenate, p. 861, containing a molasses or oil spreader.

CERAMBYCIDAE, Longhorn Borers, pp. 127–219.

REMOVAL of the bark from logs shortly after felling prevents egg-laying by all Cerambycidae (except *Stromatium*); this is the standard measure for protecting sapwood and heartwood.

Aeolesthes holosericea, p. 136. Logs of winter fellings should be barked before March in north India as the beetle is on the wing March–June. Material extracted with the bark on and seasoned in the log in timber-depots is liable to be attacked for one year from the date of felling.

Living trees which are unhealthy or wounded (particularly south Indian species) are attacked and may be eventually killed by beetles derived from felling-refuse. Control measures are, (a) clean up all felling-refuse that is serving as breeding-material, and (b) fell and convert attacked standing trees of all miscellaneous species as well as those of value for timber.

Aeolesthes sarta, p. 139. For many years control of *A. sarta* as a pest of living shade and fruit trees in and around Quetta has been attempted by cantonment, municipal and agricultural authorities. The measures are (a) maintenance of the trees of avenues, gardens, orchards, etc., in a resistant condition by good horticultural methods, (b) regular inspection to locate attacked trees, (c) pruning and repairing wounds of slightly attacked trees, (d) felling and removing badly attacked or killed trees before

November each year, (e) during a bad outbreak organisation of beetle-trapping by means of freshly cut logs of preferred food-plants (as for *Hoplocerambyx*, see later), (f) prevention of breeding in fuel-supplies by barking unattacked logs and splitting attacked material.

Aphrodisium hardwickianum, p. 142. In *Quercus incana* coppice forests that are worked for the supply of fuel to hill-stations, the damage done by *A. hardwickianum* is the accumulation of many years. In the older stands the damage reaches a degree at which the wood increment becomes negative; the amount of wood converted into frass and thrown out from the ejection-holes is greater than the current annual volume-increment of the crop. Under these conditions the remedy is to coppice the whole stand; before stacking for fuel the logs should be split into pieces small enough to ensure the death of all borers present in them, or they should be immediately exported from the forest. In younger stands in which the incidence of attack is less, inspections should be made annually to fell and remove trees which have died in the autumn or spring. These should be accompanied by selection fellings in which living trees containing living borers are cut out; marking should be based on the presence of fresh ejected wood dust, which is likely to be most conspicuous in the spring when larval activity is resumed. Felling and conversion or removal should be completed before May. If unsplit billets are left in the forest through the monsoon the beetles will emerge and no advantage will be gained. In thicket and pole-woods it might be practical to patrol with the object of detecting dead branchlets (killed by early instar larvae) which should be broken or pruned off. Cleanings should remove weak stems from overcrowded stools. Lopping should be prohibited.

If regular remedial measures cannot be organised it would be better to reduce the rotation considerably; for this purpose the weight of fuel yielded should be the criterion, not the deceptive girth-increment.

Apriona cinerea & A. germari, p. 144. If these species are abundant in plantations it is an indication that multiplication is occuring in food-plants in poor condition in areas adjoining. Killed or badly damaged plantation trees should be thinned out but the measure will have very little effect on the local borer-population unless external breeding-centres are cleaned up. See list of alternative food-plants.

Apriona swainsoni, p. 144. Climber cutting is the remedy in teak plantations.

Aristobia spp., p. 145, as for *Apriona cinerea*.

Batocera horsfieldi, p. 146. Since the damage done by a single individual in valuable timber is relatively great and the life-cycle

is long, direct measures involving tree-to-tree inspection are possible. (a) Attacks should be located by means of the ejected frass and sap on the bark or ground and the ejection-holes should be opened up and filled with tar or viscous oil and a flexible twig or splinter of bamboo thrust into the tunnel to kill the larva; the tar will kill a larva which escapes being stabbed by the probe, which should be left in place as evidence the tunnel has been treated. (b) The work of the very young larva is recognisable by an experienced observer from the presence of a black patch of liquid and frass on the bark between September and spring; the larva can be killed by cutting into the bark with a knife. (c) Trees that have been repeatedly attacked should be thinned out and converted or split for fuel. (d) During the beetle-season traps of freshly cut billets should be distributed in the area of control operations and inspected in order to discover the strength of the borer-population.

Batocera rufomaculata, p. 148.

Browne F. G. and Foenander E. C., 1937, *Malay. For.*, VI, pp. 240-254, An entomological survey of tapped jelutong trees.

Husain M. A. and Khan M. A. W., 1940, *Ind. Journ. Agr. Sci.*, X, pp. 945-959, pl. xliv, Bionomics and control of the fig-tree borer.

Damage to cultivated fig and mango trees, etc., can be prevented by enclosing the stem with stout paper coated with coal tar, or with wire gauze, 1/16th inch mesh, or by spraying the bark with a strong repellent, p. 859, during the oviposition-period. Attacked trees should be located during May–October and ejection-holes opened up with a knife; kerosene or fuel oil is squirted into the opened larval tunnel or, if the tunnel cannot be cleaned out sufficiently, a plug of cotton wool saturated with kerosene is pushed in; the wound is closed with clay (Husain and Khan).

When attacks occur on living but unhealthy trees in forest the affected trees should be felled and converted before the beetles emerge, p. 149. If regular fellings or thinnings are in progress in the neighbourhood, or if extensive damage has been caused to trees by wind or fire, the felled or dead trees should be examined in order to determine to what extent they are producing *Batocera*. Attacked material should be barked, removed or converted as may be needed to destroy the larvae in the wood.

Under unusual conditions when blazes or tapping panels (e.g., on rubber or *Dyera*, p. 148) are attacked, special measures will have to be devised (see Browne & Foenander, 1937). The possibility of catching the beetle, which has a very long life, at traps needs investigation.

Celosterna scabrator, The Babul Borer, pp. 150, 817, 840.

Beeson, 1931, *Ind. For Rec.*, XVI, IX, pp. 279-294, pls. 2, The life-history and control of Celosterna scabrator.

PREVENTIVE MEASURES.

When monocultures of *Acacia arabica* are formed without

regard to the suitability of the site uneven growth results; the young stagnating crops on poor dry soils become permanent breeding-centres for the multiplication and spread of *Celosterna* to the better areas (pp. 817, 840). Babul should be restricted to localities entirely suitable for it and other species of trees should be planted elsewhere. Species which are undesirable substitutes because they are also attacked by *C. scabrator*, are given on p. 150.

For the improvement of existing felling series there are two courses: (a) As the backward areas are gradually depopulated under the combined effects of borer-attack and remedial uprooting they should be restocked by suitable non-susceptible species, and as annual coupes are cleared replanting should be done in accordance with the characteristics of the site; this method produces irregular stocking. Or (b) The whole area should be cleaned up in the course of 3 years under a regeneration scheme designed to eliminate all the bad breeding-grounds in one operation and to interpose a 2-year period during which babul is not planted, but field-crops are cultivated and other tree-species are regenerated. Two working schemes of this kind are given in detail in Beeson, 1931, pp. 291–293. The main stipulations are (a) clear-felling of coupes over 3 years old and carrying babul under 9 inches basal girth in one extraordinary annual clearance, (b) reduction of period allowed for cultivation of field-crops from the customary 2 years to 1 year, and (c) no planting of babul for 3 years; thereafter reversion to normal methods of working.

REMEDIAL MEASURES

It is recognised in the Central Provinces that expenditure incurred on direct remedial measures is not likely to diminish proportionately the borer-attack on babul growing in unsuitable localities but may be profitable in those stands that are endangered while passing through the most susceptible ages.

Grubbing-up attacked trees: To be certain of destroying the borer, which may be at a depth of 18 inches below ground-level, the thick roots must be grubbed-up. Attack is recognisable by the fresh heap of ejected frass, see fig. 47; newly dead stems or coppice-shoots are usually an indication of current larval activity, but exudation of gum may indicate the larva has died. The cost of grubbing-up is about 12 annas per 100 plants.

Collection of beetles: During the period August—mid September when the beetle-population is greatest (p. 152), beetles can be collected by hand, feeding on small babul plants, at a cost of about 5–10 annas a 100. They will be found until November but not in numbers that can be caught economically. No experiments have been done with traps or baits; information on these accessories is needed in a properly organised beetle-catching scheme.

Oil. As an alternative to grubbing-up, the attacked plant is cut off at ground level with an axe and a small quantity of crude oil or furnace oil (p. 865), is poured into the open tunnel through a tin funnel; to prevent waste of oil a dipper of about 8 cc. capacity should be used to measure each dose; 1 gallon of oil suffices for about 500 trees. This method is the cheapest of all and does not require particularly skilled labour; it can be worked from November to February.

Chelidonium cinctum, p 155. The girdled twigs containing the young larvae turn black and are quite conspicuous. In lime and orange orchards in south India they are broken off by means of a forked stick and burnt.

Chlorophorus strobilicola, p. 156. When cones are collected for seed those which are found to be infested should be burnt.

Dihammus cervinus, The Teak Canker Grub, pp. 161, 817, 841.

PREVENTIVE MEASURES

Teak plantations in north India and Burma should not be made on land previously occupied by *Clerodendron infortunatum* unless this plant is eradicated before the teak is put in and dense patches are cleaned up from adjoining land (p. 163) A ground-fire is not sufficient to kill *Dihammus* in the roots of *Clerodendron* (p. 837); the plant must be uprooted.

Pure plantations of teak and of *Gmelina arborea* should not be adjacent to each other (p. 842)

Rapid growth in diameter during the first 6 years will (a) shorten the period during which the tree is exposed to attack, (b) make it more resistant to early larval tunnels, (c) reduce the extent of canker-formation, (d) prevent breaking off at cankers (p. 162). The presence or absence of an undergrowth (which contains no *Clerodendron*) has no appreciable effect on the population of *Dihammus* which is controlled by other factors. Cutting back weeds in the first 2 years slightly reduces the incidence of attack on teak saplings.

There is no practical method of preventing oviposition by painting the stems with repellent insecticides, or by enclosing them in sleeves of grass, etc.

REMEDIAL MEASURES

Cut back to ground-level stems of 1-4 year old plants, which are badly cankered or broken through at the canker, in order to obtain new stems. Attacked trees should *not* be cut out with the object of destroying the borer.

Glenea indiana, p. 172. An abnormal outbreak of this species in living saplings or poles means there is an excessive accumulation of felled or fallen breeding-material and possibly high stumps and top broken trees. A clean-up of the area, including the felling and disposal of attacked trees, is the remedy and the rule for the future

Glenea multiguttata and **G. spilota**, pp. 172–173. Abnormal attacks on standing saplings or poles of *Bombax malabaricum* should be traceable to excessive breeding in felling-refuse of the numerous alternative food-plants, which should be cleaned up and avoided in future.

Hoplocerambyx spinicornis, The Sal Borer, p. 173.

For literature on control measures see pp. 186–187.

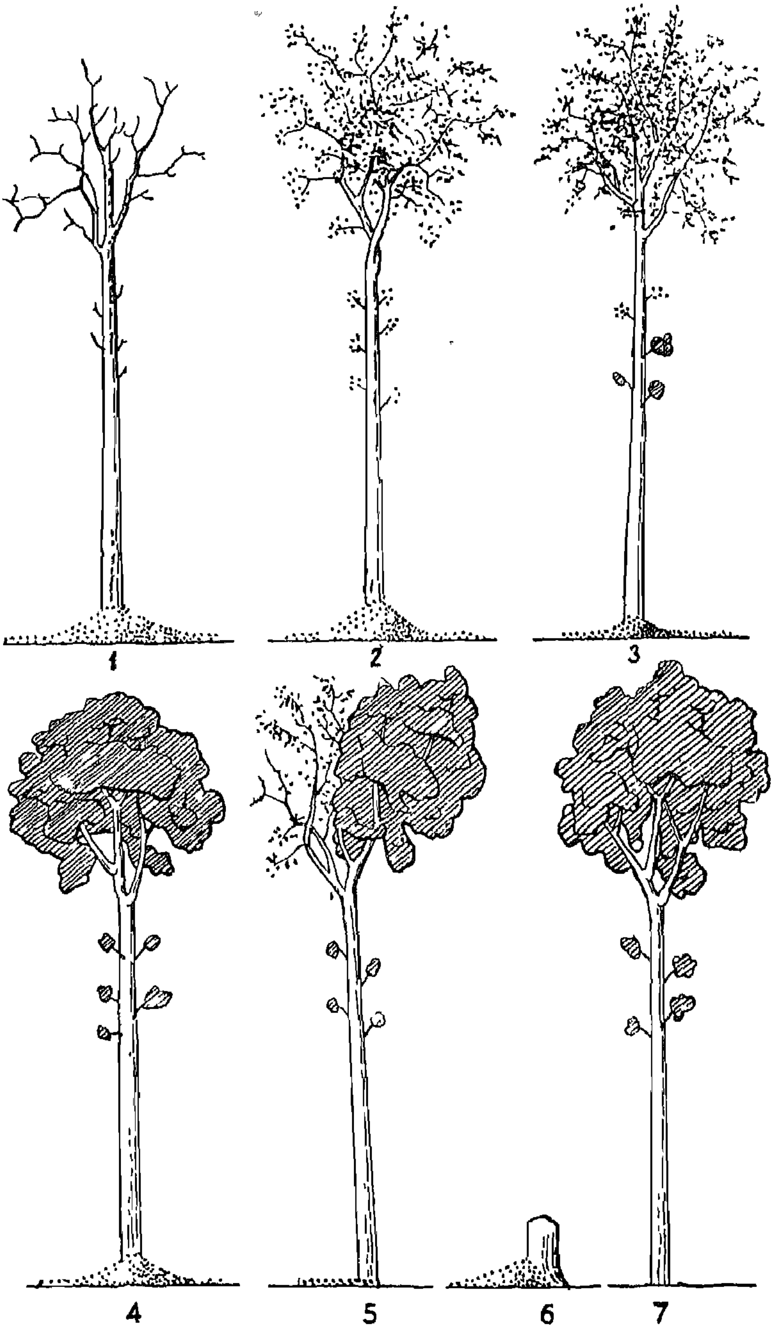
Preventive measures may be defined as those intended to keep the damage to felled timber and standing trees below a tolerable degree; and remedial measures as those intended to reduce abnormal or epidemic damage down to the tolerable degree. The former should be applied regularly as part of the normal system of management of the forest and the latter are required for exceptional outbreaks. *H. spinicornis* is under economic control when the incidence is not greater than one percent of the growing stock or alternatively one tree per acre.

PREVENTIVE MEASURES

Silvicultural: The stocking of sal forests should not be allowed to become dangerously dense, particularly in older crops. Subject to obtaining a fair monetary return and also to cultural considerations it is preferable to fell trees whenever they become exploitable rather than to retain them to the maximum age possible before unsoundness develops. At the beginning of an epidemic the incidence of attack is relatively heavier on the largest (apparently healthy) trees than on the smaller trees and such groups of mature trees form the foci of spread. The general object of all cultural operations should be the production of a healthy forest and the removal of potential breeding-grounds.

Fellings should normally be confined to the period October–March. The bark should be removed at once from all branch-wood, butts, forks, offcuts, slabs, etc., down to 8 inches diameter, which are likely to be left on the felling-area during the following rains. When sal forests are worked in the monsoon-season the logs and refuse should be used as traps (see p. 905) and all attacked refuse or unconverted trees down to 5 inches diameter should be barked or burned or both before the following hot weather. A clause should be inserted in every agreement compelling the lessee to take all convertible attacked trees in his coupe, or, if he fails to take them, to allow departmental conversion of such trees whether in his coupe or outside it.

Patrols: Regular patrols should be carried out in the cold weather by beat guards to discover standing attacked sal, windfalls, etc. Orders should be issued for the disposal of trees that are dead, showing ejected wood-dust or an excessive flow of resin, according to the importance attached to their abundance and distribution (see also fig. 199). A specially careful patrol must be carried out after each year of abnormally high rainfall (see pp.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179, 185).

The object of annual preventive control is, before the following rains, to fell all attacked trees and to convert them or to dispose of unconverted material down to 8 inches diameter by removal or burning so that no beetles emerge. During epidemic conditions in years of exceptionally high rainfall material down to 5 inches diameter should be rendered harmless.

REMEDIAL MEASURES

In an epidemic the following additional measures have to be organised. i, *Enumeration of attacked trees*, ii, *Disposal of* attacked trees by extraction, conversion or burning. iii, Collection of beetles at trap-trees. Whether all these operations can be carried out over the whole area and throughout the year depends on local conditions. It may be necessary to draft in extra staff, procure labour, sawyers, transport, etc., at seasons when they are scarce. For details of the organisation in the C. P. epidemic of 1924–1928 see Muir, 1929, *Ind. For. Rec.*, XIII, v, pp. 32–36. For maps showing the incidence in the U. P. epidemic of 1916–1923 see Beeson and Chatterjee, 1925, pls. i-iv.

i, Enumeration of attacked trees

The ideal is total enumeration of all attacked trees and it is very important to achieve this in the first season of special operations, so as to have a clear idea of the incidence and the area of the outbreak and the magnitude of the operations. Control undertaken in the initial stages of an epidemic is far more profitable than the same expenditure in following years. The enumera-

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Fig. 199, **Hoplocerambyx attack on Shorea robusta. Types representing different intensities of infestation.**

Type 1. Crown dead, leafless; epicormics leafless, wood-dust in large heap.
2. Crown dead, brown; epicormics dead, brown; wood-dust in large heap.
3. Crown dead, brown; epicormics or bark dead in upper part, alive in lower part of trunk; wood-dust in heap more than 3 inches deep or less abundant.
4. Crown entirely alive, green; epicormics green; wood-dust in large heap.
5. Crown partly alive, green and partly dead, brown; epicormics green; wood-dust scattered, less than 3 inches deep.
6. Stump with large heap of wood dust.
7. Crown entirely alive, green; epicormics green; resin abundant or absent; wood-dust scattered or scanty.

Types 1, 2, 3, and 6 should always be removed; types 4 and 5 may be omitted in an incomplete clean-up; type 7 should not be felled.

tion should classify trees by girth-classes and by types of attack (i.e., by some or all of the types shown in fig. 199 and p. 903). At the onset the incidence of attack is relatively heavier on trees of over 5 ft. girth than on trees of $1\frac{1}{2}-5$ ft. girth-classes; 20 percent of the total of the first year's attack may be trees of over 5 ft. girth. Later this preponderance falls off rapidly and eventually the incidence is uniform throughout the growing-stock, i.e., the percentage of trees attacked in each girth-class above $1\frac{1}{2}$ ft. is the same. (This means that the liability of any tree to attack is then governed by the laws of chance and suggests that the thinnings done by the borer have produced a forest composed of a uniformly resistant growing-stock. Statistics of the relative liability of different girth-classes to attack have been given by Beeson and Chatterjee (1925) and Beeson (1927) for Thano, U.P., by Beeson (1927) for Kalagarh and Lansdowne, U. P., and by Atkinson (1927), Beeson (1927) and Muir (1929) for Balaghat and South Mandla, C. P. (see references pp. 186, 187).

Enumeration should be done after the rains and preferably started in December; if started earlier it will miss or not record correctly most of the trees which die during the cold weather and spring. Otherwise the earlier areas must be worked over a 2nd or 3rd time to locate the later deaths.

ii, Disposal of attacked trees

Types: It must be decided what proportions of the enumerated trees will be extracted, converted on the spot or disposed of by burning. If it is estimated that the total number of trees cannot be dealt with, the available labour should be concentrated on those trees having the largest numbers of borers in them, neglecting those having relatively small numbers of borers per tree. The following classification includes the commonest types of attack; as the cold weather and spring progress types 2 and 3 may pass into 1; and 4 into 2 or 3 (see also fig. 199):—

	TYPE
Crown entirely dead, i.e., leafless or the leaves brown	
Crown foliage fallen	
Epicormics leafless; wood-dust in a heap more than 3 inches deep	1
Crown foliage brown	
Epicormics dead, brown; wood-dust in a heap more than 3 inches deep	2
Epicormics or bark dead in upper part, alive in lower part of trunk; wood-dust in a heap more than 3 inches deep, or less abundant	3
Crown partly alive, green and partly dead, brown	
Epicormics alive; wood-dust scattered, less than 3 inches deep	5
Crown entirely alive, green	
Epicormics green; wood-dust in a heap more than 3 inches deep	4
Epicormics green; wood-dust scattered or scanty	7
Stump with heap of freshly ejected wood-dust	6

The numbers of beetles likely to mature and emerge from each

of these types depends on the girth and bole-length of the tree and the proportion of the borer-population that has been destroyed by competition, disease and natural enemies. There is a great variation up to a maximum of 450 beetles in a tree over 5 ft. in girth. A rough guide to the average numbers maturing per tree is :—

Girth-class	Types 1 and 2	Type 3	Type 4	Type 7.	
2′–2′11″	70	40	20	10	Beetles
3′–4′11″	140	100	40	25	
5′ and over	260	300	80	50	

Type 5 falls within the range of types 4 and 7; the stump, type 6, of a large tree contains a high number of borers considering its small volume. The number of larvae present at the beginning of the life-cycle is of course many times the above figures. For further details see Beeson and Bhatia, 1939, *Ind. For. Rec.*, V, No. 1, pp. 116-119. Of the total borer-population of a tree with a dead crown (Types 1–3) 60–70 percent occurs in the bole and 40–30 percent in the crown branches; a tree with a green crown (Types 4,7) has a very small percentage or none.

Barking: For the disposal of affected trees barking is sufficient only up to the time the larvae begin to enter the wood (see p. 175). Thereafter the trunks and branches must be burned. Stumps should be barked at once whatever the date of felling.

Burning: The object of burning is to heat the tunnels or pupal chambers enough to kill the insects. It is not always necessary to incinerate the heartwood. To prepare small trees for burning, elaborate stacking is not needed but large trees must be logged and carefully stacked to get good results. The logs should be arranged around a stump, in an open crib, each layer of logs at right angles across the layer below. Plenty of small stuff should be placed at the bottom of the stack around the heaviest logs. This method of stacking gives good aeration and burns effectively if stoked for some time after lighting; if the kindling material is piled on top of the stack there is a fierce blaze which may damage standing trees and the large logs do not char through to the depth of the pupal chambers. For details see Muir, 1929, pp. 34, 36.

iii, Collection of beetles at trap-trees

For use as trap-trees select sal (a) unsound or injured by fire, wind, fellings, etc., (b) silviculturally undesirable, (c) attacked types 4 and 5. The sapwood and bark are the attractive parts, hence those trees in which the ratio of heartwood is lowest, are the least wasteful if marketable timber must be sacrificed. Logs 3′–3′6″ girth are 3–4 times as attractive as those of 2′ girth which are 3 times as attractive as those of 1′6″ girth; poles of smaller

girth are best used several together in one spot.

Start felling trap trees soon after emergence has begun and continue during the period of high abundance of beetles; see pp. 183-186 and figs. 58,59 and estimate the dates and the period with reference to the daily rainfall during the season of trapping, installing a rain-guage specially if none is near. Traps should be located where attacked trees and felling-refuse are most abundant, and where bonfires have been burned, and some should be tried in apparently free areas for reconnaissance. Arrange labour to fell, log and operate traps on a preliminary basis of, e.g., about 10 percent of the enumerated attack or 2 trees per acre but be prepared to increase the scale if large quantities of beetles are caught at the outset. A trap-tree which catches as many beetles as could mature in it is justified (see figures p. 905). The biggest yield of one tree is over 1,000 beetles in 24 hours and of a series of trees is 515 per cooly per day and 87 per cooly per working hour.

On the 2nd to 4th day after felling cross-cut the trap-tree into smaller logs and billets; this is equivalent to felling a fresh tree. Later cross-cut again and partially strip or bruise the bark in order to expose fresh sap. The range of attraction of a trap is at least 2 furlongs to leeward; long range attractiveness quickly falls off during the first few days but remains strong locally for weeks. Traps should be inspected daily; and well searched beneath and nearby; the beetles assembled on them are easily caught; the heads should be pulled off and kept in tins or bags to be counted at the forest guard's quarters in the evening. When the yield falls off visits should cease and collectors should be concentrated on more recent fellings. If the traps have not been barked completely during collection this should be done before the end of the monsoon. For further details see Beeson, 1928, Muir, 1929, Appendix B, Watts, 1928.

In places which are inaccessible during the monsoon the collection of beetles cannot be done. Trees should be felled at the latest possible date and left to act as traps for oviposition until the area is again accessible after the monsoon when they should be barked or burned.

Lophosternus hugelii, p. 187. (i) Dry sandy soil in fruit orchards is favourable for egg-laying and the survival of larvae. Sites with soils unsuitable for fruit trees should be improved by removal of all undecomposed orchard debris and by manuring with well rotted organic matter. (ii) Paradichlorobenzene applied at a depth of 3 inches and at the rate of 1 oz. per linear foot in a circle around the base of a tree, vapourises effectively over a radius of 6 inches in the course of 6 weeks, i.e., during the whole period of hatching of the eggs (*Prog. Rep. Hill Fruit Res. Scheme*, Chaubattia, U. P., 1941).

Macrotoma spp, pp. 189, 190. Oviposition in fuel stacks is prevented by removing the bark of logs felled after March. Damage in the forest indicates the need for extra enumerations and coupes to remove dry trees.

Massicus venustus, p. 191. Attacks on standing living trees should be controllable by measures similar to those used for *Hoplocerambyx*. For efficient utilisation of trap-trees in south India the flight-period of the beetle must be determined experimentally.

Monochamus versteegi, p. 193. In citrus orchards in Assam the regular remedy is to kill the larva in its tunnel by thrusting in a wire probe. The wound should be tarred and closed with clay.

Pachydissus birmanicus, p. 198. The ecology of this species has to be investigated before control can be devised.

Perissus dalbergiae, p. 199. This borer is characteristic of poor quality and cut-back areas in shisham plantations. Its presence may be taken as an indication of unhealthy growing-conditions under which the tree is on the point of dying off. Evidence of bad soil, drought or shisham root-fungus should be looked for. If the group of dying trees extends rapidly, fell and burn or remove the affected timber to prevent the production of a large population of *Perissus*, *Sinoxylon* and other borers, which would spread to healthy trees. Some of these trees might be killed before the flow of gum had overwhelmed the borers.

Plocaederus obesus, p. 200. Control measures for this species in tapped *Sterculia urens* have not been worked out; it should be possible to modify the tapping system so that wounds heal more readily.

Quettania coeruleipennis, p. 203, is controlled on fruit trees by cutting off affected branches at the time of pruning.

Sthenias grisator, p. 205, as a pest of vines, ornamental climbers and shrubs, can be checked by collecting the beetles and pruning and burning the girdled shoots as soon as withering is noticed.

Stromatium barbatum, p. 206.

PREVENTIVE: Because of its long life cycle and restricted emergence-period (pp. 208, 209, figs. 66, 196) the borer can be eliminated from sawmills, factories, warehouses, museums, etc., by regular inspection and destruction of attacked stock and mill-refuse once a year, preferably in the spring. In recently built or furnished rooms the woodwork and furniture should be suspected of introducing the pest. Slightly damaged stock should be disinfected and repaired. A bad infestation builds up only after prolonged neglect and accumulation of undisturbed close-stacked material. It ought not to be necessary to use wood-preservatives; if these are considered desirable, impregnation or prolonged steeping must be done as for Bostrychidae, pp. 884–886; superficial

treatment is ineffective as the larva bores through thin varnish, paints, dips, etc. (p. 207).

REMEDIAL: Damage to manufactured solid wooden articles, which is revealed later by holes, dust or the noise of the larva at work, usually results from an attack which started years previously in the factory. The remedy is as prescribed for Bostrychidae, e.g., injection of or soaking in a fumigant-contact poison, sterilisation by heat, p. 888, and replacement of parts badly bored. An infestation of stacks of thin articles like veneers, plywood, laminated boards, battens, is checked by turning over the material, picking out the larvae and restacking differently.

Stromatium attack on dead branches of stagheaded trees in the forest and dying-back fruit and citrus orchards is always secondary to the presence of dead wood.

Xylotrechus quadripes, p. 214, is controlled on coffee estates in south India by (a) uprooting and burning attacked trees during the monsoon, (b) scrubbing the stems in October, November to dislodge eggs and young larvae along with bark-flakes, moss, etc., and (c) swabbing the stems in October, November with a 10 percent solution of wood tar distillate emulsion to kill eggs and larvae and to prevent oviposition (Wood tar distillate emulsion, 80 percent, is made by the Bhadravati Iron Works, Mysore). Cashew nut oil emulsion is also an effective wash for killing eggs. Both operations (b) and (c) are done in foci of attack and on a couple of hundred of the surrounding trees. The cost of (c) is Rs. 6–8 for a full acre of coffee. *Circ.* No. 57, *Dept. Agr.*, Mysore, 1937.

Xystrocera festiva & X. globosa, p. 218. In Java *Albizzia* trees used for shade in tea gardens may be treated after attack by *X. festiva* by drenching the bark with paradichlorobenzene 1 part, kerosene 10 parts, applied with a sprayer having an ordinary coarse spray nozzle but only on the infested part of the trunk as the living cambium of young trees is very delicate. The larvae are killed by the oil, and callus rapidly covers the wound. An alternative is simple cutting open of the bark-tunnels to expose and kill the larvae, or to inject the fumigant. In Malaya *Albizzia* over tea is much defoliated by *Terias hecabe* and *Clania crameri* and is thus more susceptible to *Xystrocera* attack; it is considered better to use other species of trees for shading tea.

For similar borers the remedy is spraying the trunk and large branches during the oviposition-period with sodium arsenate 1 lb. dissolved in 20 galls. water to which 1 gall. miscible oil is added. Wood tar distillate emulsion (see *Xylotrechus*) should be tried. Shade trees attacked by *X. globosa* in towns and along roads in India can be treated by these methods. Local breeding should be stopped by removing over-mature and dying trees and by repairing wounds on those still capable of resistance.

CHRYSOMELIDAE, p. 219.

SPRAYS of general value for chrysomelid beetles and larvae feeding on foliage are—(a) Lead arsenate 4 lbs., fish oil or linseed oil 1 lb. (1 pint), water 100 galls., used as a stomach poison early in the season to kill beetles and young larvae; the oil makes the spray effective for a long time after application; for a 2nd spray 3 lbs. of arsenate to 100 galls. water is sufficient. (b) Nicotine sulphate 1 quart, good quality soap 4 lbs., water 100 galls. as a contact poison for larvae or pupae.

Calopepla leayana, p. 221.

Garthwaite P. F., 1939 *Ind. For. Rec.*, v, No. 2, pp. 265-274.

Silvicultural: *Gmelina arborea* should be planted only on optimum sites, and a pure plantation area should be divided by strips of natural forest, wide enough to allow the grading of overhead cover on the edges so as to avoid interference with the light requirements of *Gmelina*.

Biological: Some work has been done on the parasites of Calopepla (Garthwaite, 1939) but further information is needed on the alternative hosts of *Brachymeria*, p. 488, and the egg parasites and on the parasites of other cassidine species, p. 494, before natural control can be improved. It is improbable that mass-breeding and liberation of parasites early in the season can be devised on a practical scale.

Mechanical: (a) Beetles hibernating in shelters, e.g., under bark, in cracks and crevices, in the hollows of bamboos, in thatch, etc., can be collected by hand; this can be facilitated by destroying the majority of natural shelters so that the beetles are forced to congregate at the remaining few accessible points. Further investigation is needed of the preferred natural hibernating conditions and the possibilities of artificial sheltertraps. (b) When overwintered beetles return to the plantations in May–June they can be hand-collected from the low foliage before they lay eggs. (c) In August during sunny breaks in the monsoon the 2nd generation beetles are attracted to white surfaces; large sheets of cloth or metal having a central funnel or bag as described by Garthwaite, 1939, might form the basis for the design of a mechanical trap.

Chemical: The value of spraying or dusting a narrow poison-belt of foliage along the edges of plantations during the period of migration of the beetles after hibernation needs investigation.

Estigmena chinensis, p. 225.

Deogan P. N., 1937, *Ind. For. Rec.*, Silv., II, No. 4, The silviculture and management of the bamboo Dendrocalamus strictus.

Silvicultural: This borer is one of the causes of bending and congestion in bamboo clumps; dense clumps and split culms

provide the beetle with shelter during the hot dry season. The cultural measures prescribed for the treatment of congestion, cleaning, tending and felling of clumps are also measures for the control of the pest (see Deogan, 1937). In a year when *Estigmena* damage increases abnormally, immature attacked culms should be cut in those coupes where extraction is going on; attacked culms should be sorted from the sound ones and removed at once to open bare ground distant from the forest; after prolonged exposure to the sun the beetles will die in the culms or will disperse and die during the hot season.

Plagiodera versicolora, p. 229. Spray with the lead arsenate mixture prescribed above, p. 909.

CURCULIONIDAE, Weevils, p. 250.

WOOD-BORING Curculionidae of all types are prevented from laying eggs by removing the bark from logs shortly after felling.

Alcides spp., pp. 255–257. (a) Against species of *Alcides* which bore the leading shoots of young saplings nothing can be done except pruning and destroying the killed shoot before the beetle emerges. Crops liable to this type of damage should be grown in close espacement in early youth.

(b) Against species which attack fruits no preventive measures are practical except that when seeds are collected from selected trees infested fruits should be destroyed and not simply rejected. For **Alcides porrectirostris** the spraying of walnut groves with lime-copper sulphate-paris green-solignum mixtures every 10 days beginning from May is advised.

Apoderus sissu, p. 259. It is not possible to prevent the beetles from swarming on the new flush of *Dalbergia sissoo* in spring, hence the abundance of the overwintered population is the factor that decides how much damage will be done in spring. Measures which prevent defoliation by *Plecoptera reflexa* and consequent flushes late in the year will also decrease the abundance of *A. sissu* at the close of the monsoon. Epidemic outbreaks of the leaf-roller must be regarded as secondary effects of defoliation by the leaf-eating caterpillars. An outbreak in nurseries or line sowings should be treated by shaking the seedlings or dragging a rope across the lines to dislodge the rolls, followed by sweeping up and destroying the fallen rolls. The trimmings of affected cuttings (if pruned in leaf) should be burned.

Defoliation by species of **Astycus**, p. 261, and other weevils of similar habits is characteristic of cultivation on cleared jungle sites for crops like tea, rubber, tung, etc. with or without shade trees, and regeneration of forest crops by taungya, rab, etc. Local breeding by *Astycus* on such sites is the result of clean cultivation or exposure which permits the growth of certain kinds of weeds and grasses. It is now recognised that clean weeding is undesira-

ble, that soil fertility is regenerated and that erosion is prevented by the use of cover-crops or by the selective growth of natural jungle covers, which are thinned or controlled according to the general needs of protection. Soil-breeding insects are controllable by the proper application of this principle which has to be worked out for the crop and the locality.

Calandra spp., p. 262: see *Alcides* (b).

Cryptorrhynchus rufescens, p. 265, is considered to be an indicator of previously existing disease or weakness (see p. 869). Excessive multiplication can be checked by barking large infested pines (e.g., dying or dead standing seed-bearers) and burning small trees attacked by *Peridermium*.

Cyrtotrachelus dux & C. longipes, pp. 267–273.

Incidence: The population-density of beetles of *Cyrtotrachelus dux* is relatively low per acre of bamboo forest. Many other factors damage or kill the young growing culms of bamboos early in the monsoon season, e.g., monkeys, which break or snap off the brittle shoots and leave the chewed remains in heaps near-by: sambhar and cheetal break the culms with their horns: pigs and porcupines dig up the rhizomes bearing new culms: dynastid beetles excavate holes and enlarge the incisions made by *Cyrtotrachelus*: trypetid larvae accelerate the distortion and decay of growing shoots: *Estigmena chinensis* makes cavities and checks growth: woodpeckers searching for boring larvae peck out large cavities: men of some jungle tribes break off shoots in order to obtain the *Cyrtotrachelus* larvae: a virus disease arrests growth and starts putrefaction. It is therefore essential to be sure just how much damage is due to *Cyrtotrachelus* before embarking on general control measures.

Hand-collection: Owing to the small population of beetles per acre and the difficulty of locating pupal sites it is not practical to search for and destroy the pupal cell containing the beetle during the period October–June. It is useless to collect and destroy the fallen dead culm tops as none contain larvae. The only possible direct measure is the capture of the beetle at the beginning of the monsoon, June–August. Beetles are large insects and conspicuous while resting on the bamboos or in flight: they are sluggish and easily caught when engaged in feeding. "In the Gharakota Reserve, Saugor Division, C.P., this method of collecting the beetles has been resorted to with considerable success". (Witt, 1913, p. 272). Some aboriginal tribes, e.g. in Bastar State, collect the larvae of *Cyrtotrachelus* for food and it should be possible to put their customs to practical use.

In *Ind. For. Rec.*, Silv., ii, No. 4 (1937) p. 171, it is recommended that all attacked culms of last year should be cut and burnt in winter. This does not apply to *Cyrtotrachelus*. In para. ii, *lit. cit.*, it is recommended that a light ground fire should be

run through the infested areas. This does not apply to *Cyrtotrachelus*.

Silvicultural: Damage is less in well-thinned and exploited areas than in stands of numerous dense clumps. There is no appreciable difference in the incidence of attack under varying degrees of overhead, low shade or high shade.

Hylobius angustus, p. 276. Damage by the beetle to leading and lateral shoots of conifers is preventable by dealing with the larval breeding-material. Attacked saplings and poles should be uprooted and burned in early summer. Areas where young trees are likely to be injured (p. 277) should be specially patrolled after fellings, storms, etc., to locate probable foci of outbreaks and to thin out injured and dying plants, and to free those that are crushed by boulders, fallen trees, felling-debris, etc.

Myllocerus spp., p. 280. Nothing can be done against migratory dispersing swarms of beetles unless it is feasible to spray (with lead arsenate, p. 861) or dust with Paris green (1 part in 8 parts of dust) or with wood ashes moistened with kerosene. A partial remedy for low plants is jarring or sweeping the foliage over buckets containing kerosened water. Where weevils of this group are regular defoliators, an investigation is needed of the larval food and breeding-grounds; control is likely to be connected with conditions of shade and soil flora, as for *Astycus*, p. 910.

Pagiophloeus longiclavis, The Mahogany Collar-borer, p. 285.

PREVENTIVE MEASURES

The natural food-plant of the collar-borer is *Cedrela toona* in which it breeds in greater abundance than in young *Swietenia macrophylla* in mahogany plantations. The most important control measure is reduction or elimination of the breeding-grounds in natural forest in the neighbourhood of plantation and regeneration areas (p. 841).

From felled trees of *C. toona* the bark should be removed from the smaller bole-logs and from all the branchwood over about 3 inches girth shortly after felling. Alternatively the branches may be cut up into billets and used as traps (see below). Dying or stagheaded trees should be located and felled and disposed of as above. The width of the danger zone may be put at 4 miles if a complete cleanup of a large series of coupes is contemplated. In some localities the collar-borer is entirely absent from mahogany plantations and it is likely that no dead or felled *C. toona* occur in the neighbourhood.

Shade: Liability to attack is greater in mahogany plantations in open sites than in those with overhead shade given by tree-canopy or by undergrowth or by cover-plants. Deep undergrowth sheltering mahogany in clear-felled sites prevents in ceaso of attack more effectively than does overhead shade of tree-canopy. Weeding and cleaning operations in the first few years

should retain jungle regrowth between the lines so that it protects without interfering.

Shoot-borer attack: The attack of the shoot-borer, *Hypsipyla robusta*, is very probably one of the factors attracting the collar-borer to mahogany plantations. Hence, reduction in shoot-borer attack is likely to be accompanied by reduction in collar-borer attack. The protective effect of overhead and lateral shade works equally against both pests. (see p. 805 and Control Measures for *Hypsipyla robusta*).

REMEDIAL MEASURES

Traps: The most suitable form of trap is a billet of freshly felled *C. toona* about 2 feet long and 6 to 10 inches in girth, but all available branchwood or small pole wood may be used; twigs are not worth using; bark slabs stripped from large logs are useful for a short period, which is not more than a few days in the monsoon. The trap-billets should be laid on the ground in shade, distributed singly, over a wide area in the neighbourhood of regeneration areas and mahogany plantations; they should be inspected at frequent intervals for a fortnight and the beetles which shelter underneath them should be destroyed by squashing (at a distance from the trap). Billets which are no longer attractive should be replaced by fresh ones. In the dry weather (May) billets are more attractive if the bark is loosened; this is unsuitable during the rains.

Single distribution of billets is the most economical way of using the trap-material. Heaps of several billets can be used if there is plenty of material, or if inspection cannot be organised except along routes daily frequented by the labourers. Some form of report or counting of the catches is desirable as a check on the inspection. Although the beetle can live for 8 months and throughout the autumn, winter and spring, the period during which trapping-operations can best be carried out is May to September inclusive. The population is most abundant, i.e., the biggest catches will be obtained, after the monsoon has set in. The greatest benefit will be obtained from trapping-operations that are started *before* planting up with mahogany and during the first 2 years of its life. Other species of Meliaceae are likely to be food-plants of the collar-borer. It is known that *Aglaia roxburghiana* does not support it and is useless for traps.

Removal of attacked mahogany: There is practically no advantage in pulling up mahogany plants attacked by the collar-borer unless the infestation is exceptionally heavy, as very few of the plants recognised as attacked contain living borers. The population of borers inside a mahogany plantation is only a small fraction of that in the area as a whole, consequently labour is more profitably employed in trapping emerged beetles than in destroying larvae.

Rhynchites spp., p. 290. The ecology of these twig-girdlers is insufficiently known. Control may be determined by such factors as shade and alternative food-plants or hereditary predisposition of the tree. Young *Hopea parviflora* exhibits distinct types of branching, one wide branching, another virgate and another clean-boled with a conical crown; as seed is most easily collected from the wide-branching type there is a tendency to raise plantations susceptible to the attack of twig-girdlers and borers.

Rhynchophorus ferrugineus, p. 291. As healthy palms are not liable to attack they should be grown vigorously from the start and kept in a sound condition. The roots of young palms should be mounded over and covered with a layer of soil 9 inches deep. The trunks of young palms should not be injured by cuts made for the purpose of climbing. Old leaves should be cut off cleanly at a distance of a foot from their bases, not broken or pulled away. Wounds of any kind should be tarred. As *Oryctes rhinoceros* makes holes which facilitate attack by *Rhynchophorus* it should be exterminated by the measures given later (Scarabaeidae, p. 922).

Dead palms, and trash, palm logs used for buildings and bridges, etc., should be destroyed if they have become breeding-material and are producing beetles. Larvae boring in living palms should be killed by injecting a fumigant, p. 863, into the tunnel which should afterwards be cleaned, sterilised with tar or phenyl and plugged with clay. Traps of freshly cut sappy palm logs can be used to catch beetles when abundant and particularly at the time the palm crowns are cleaned.

Sipalus hypocrita, p. 292. Attack by this species on living trees is believed to be secondary and is usually accompanied by other wood-borers. Prompt felling and conversion is necessary if the timber is to be saved.

Trigonocolus brachmanae, p. 293. In plantations of padouk, *Pterocarpus dalbergioides*, (in the Andamans) young plants become liable to attack after reaching a height of 18 inches and this liability remains during the first 2 years of growth. Damage is most severe in heavily weeded stands and in open grassy places. It may be reduced by making weedings light and frequent, so that the leading shoot of the padouk is free but the ground between lines is covered with weeds and undershrubs. If the crop closes up rapidly and forms a complete canopy the trees are more resistant and the borer-attack has no lasting effect on the subsequent development of the sapling if other conditions are favourable.

Annual Reports, Andamans, 1908-1911 and 1934.—*Ind. For.*, LX, pp. 122, 123.

DERMESTIDAE, Woolly Bears, Skin Beetles, p. 295

DAMAGE by **Anthrenus** to insect collections, herbaria, museum specimens, etc., is prevented by (a) keeping the specimens in closed boxes or cupboards in which napthalene dust or a deposit

of napthalene dissolved in benzene is permanently in excess of evaporation, or (b) poisoning the material with mercury bichloride mixture (p. 877). For disinfection after attack a saturated solution of napthalene in 2 parts creosote, 1 part carbon disulphide is exposed on a swab of cotton wool. Stored furs, woollen clothing, carpets, brushes made of hair, felt linings, etc., are similarly protected by packing with plenty of napthalene dust (either freely distributed or enclosed in bags of muslin); inspection and airing at least once a year in the warm weather is desirable. Shikar trophies, skins, stuffed animals, etc., should be poisoned by the taxidermist at the time of curing and mounting. As a remedy painting or soaking with turpentine containing 10-12 percent orthodichlorobenzene is used; horn and bone should be cleaned with turpentine. Useful traps are small boxes containing pads of woollen cloth soaked in oil or alcoholic extract of fish meal; a sardine tin with remains of oil, etc., will serve the purpose. Larvae of carpet beetles, clothes moths, etc., are attracted.

LYMEXYLONIDAE, p. 313

Atractocerus reversus, p. 315. The best procedure for extraction of logs of *Boswellia serrata* is to remove the logs (with the bark intact) as quickly as possible after felling and to store them in piles under shade, sterilising the ends and all abrasions on the bark by swabbing with creosote-oil mixture and covering with an anti-split mixture (p. 887). Logs that are not extracted quickly should have the ends and wounds swabbed with oil so long as they remain in the coupe. The object is to keep the bark alive and green as long as possible. Logs that are attacked in the coupe should be converted at once on arrival in the depot. Logs from which the bark is removed soon after felling will not be attacked by *Atractocerus* but are liable to be bored by *Platypus*, *Xyleborus*, etc., while the surface is moist and by *Sinoxylon*, *Schistocerus*, *Minthea*, *Trogoxylon* and other powderpost beetles when the surface has dried slightly. If the object of barking is rapid air-seasoning in the coupe to reduce weight for transport, the barked log must be protected against other borers. All remedies are incompatible with air-seasoning in the log except very accelerated drying-out, i.e., raise one end from the ground on a skid and rotate the log at intervals of a few days to obtain uniform rapid drying of the surface. At sawmills dispose of sawing refuse because *Atractocerus* can complete its development in large, fairly dry slabs and offcuts.

MELOIDAE, p. 316

Blister Beetles are difficult to control when they appear suddenly in swarms and may complete the damage before being detected. Although not readily killed with ordinary stomach poisons, fluosilicate dusts have been used to advantage, barium fluosilicate being the safest. Beetles of **Mylabris** are easily collected by hand and on the wing.

PLATYPODIDAE, Pinhole and Shothole borers, pp. 324–347.

CONTROL measures applicable to Platypodidae are also valid for other pinhole and shothole-borers of timber of the scolytid genera *Trypodendron*, *Webbia*, *Xyleboricus*, and *Xyleborus*, pp. 391–404. Because of the very large number of species of pinhole-borers, most of which are polyphagous, and because each species of tree is the food-plant of several species of Platypodidae and Xyleborinae, it is rarely possible to prescribe specific measures. The following general principles will serve in shaping the control most suitable for a particular locality.

PREVENTIVE MEASURES.

Felling-dates: In tropical forests there is practically no seasonal periodicity in the abundance of pinhole-borers; trees are attacked within a few days of felling throughout the year. The temperate winter and subtropical dry seasons are relatively immune periods but advantage can rarely be taken of them.

Felling-refuse & extraction: The protection of logs before extraction is made more difficult in proportion to the extent that borers are allowed to multiply on felling-areas. In small coupes felling-refuse can be made less infectious by exposing it in sunbaked open places, or by using it as traps in humid shaded spots and burning it after attack. In extensive lumbering operations with large annual coupes adjoining, and with the logging paths running through earlier coupes, and in selective extraction which leaves much crown and bole timber on the ground and rejects whole trees of inferior miscellaneous species, the danger of pinholing reaches very serious proportions. Under such conditions partial disposal of the refuse is not worth the expenditure and it is imperative to organise the sequence of felling, logging, dragging, detention in depots and export therefrom so that logs are exposed to danger for the shortest possible time; pinhole-borers that enter a log are carried away inside it and the depreciation of the timber continues until it is sawn. Rapid extraction from the forest to safe depots is therefore a preventive measure of first importance.

Barking: For many species of trees removal of bark increases the intensity of attack; for most species retention of bark intact does not prevent attack; for a few species retention of the bark postpones attack so long as it remains green and alive. Indian species with protective barks are *Adina cordifolia*, *Bombax malabaricum*, *Boswellia serrata*, *Dillenia pentagyna*, *Heteropanax fragrans*, *Hymenodictyon excelsum*, *Meliosma simplicifolia*, *Michelia champaca*, *Premna bengalensis*; by experiment several others will doubtless be found. All measures which will keep the bark alive in such species should be used, e.g., postpone the logging and trimming of the felled tree until just before logs are dragged; store in deep shade or in water; coat

the ends of logs with anti-splitting compounds, p. 887.

Squaring logs of many species decreases the amount of pinholing owing to exposure of the heartwood which is not entered.

Seasoning & depots: Intermediate or transit depots in which logs removed from the coupe await despatch to the mill or main timber depot are of 3 types. (a) In dense shade under the closed canopy of rain forest; the object is to keep the timber cool, moist and dark. The depot consists of several alcoves or plots a short distance off the terminus of the dragging route, only undergrowth and poles being cleared to obtain space for piles. It is an advantage if the bark is occupied by sapwood-borers or termites. (b) In the open in full sun; the object is to heat the bark and dry out the wood quickly. Logs should be lined up N & S, and raised on skids, not piled, so that they can be half turned at intervals to check borers entering on the lower shady side. (c) In water; the object is complete submersion. The floaters should be immersed as much as is obtainable by tethering to sinkers, or by collecting loose behind a boom so that they can be rolled over or depressed daily. In tidal waters it suffices if the logs are covered by water once a day.

At the sawmill or sales depot the usual hygienic principles should be enforced, i.e., prevent any local breeding of borers by constant inspection and destruction of breeding-material produced by milling operations or the importation of infested timber. The method of air-seasoning or water-seasoning adopted at the mill must be a compromise determined by the liability of the particular species of timber to attack by powderpost-beetles, cerambycid heartwood-borers, weevils, etc., as well as by pinhole-borers. In most cases air-seasoning in the sun raised on skids with frequent rotation is the best method; when the moisture-content of the wood is down to about 50 percent there is not much danger from pinholes. It is sound practice to convert at once any log showing signs of attack even though the products are inferior and the fulfillment of orders for first class stuff is delayed.

Repellents: Various substances have been tried on logs in tropical forests to deter pinhole-borers, including mud, cowdung, tar, spraying with oils, water-soluble salts, dusts, etc., but none will stand up to alternations of heavy rain and hot sun except thick layers of sticky band mixtures (p. 860) which are expensive and messy. A thick oil, carbolineum or similar deterrent is worth using in barked logs stored under cover or in dry winter and summer climates. Poisoning standing trees by injecting arsenicals into frill girdles does not prevent pinhole-borer attack.

Sawn timber: Planks and scantlings sawn from green softwoods or the sapwood of unseasoned logs are liable to attack so long as moist and any method of speeding up the drying reduces the danger period. End racking in the open air for 1 or 2 weeks before stacking will ordinarily kill off pinhole-borers present in the

wood and prevent fresh attack; the disadvantages are extra costs of handling, extra yard space and splitting or warping when the weather is variable. As converted sapwood of most timbers is also liable to bostrychid attack for which either treatment with creosote, p. 884, oil or salt solutions, p. 886, or kiln drying (p. 888) is prescribed, the standard process will serve for pinhole-borers too, provided it is preceded by air-drying.

Platypodid attack on living trees

Regular pests: The difficulties of controlling pinhole-borers which regularly breed in living trees in natural forest are illustrated by the case of **Crossotarsus impar** in Malaya (p. 329). Although abundant there is no reason to suppose it has appeared so far in epidemics. The production of large populations will be favoured by silvicultural operations which frequently result in large areas of almost pure meranti (*Shorea*) forest. Browne (1936) points out that one cannot say whether the encouragement of the species of *Shorea* apparently resistant to *C. impar* would be effective; the resistance may not be intrinsic but conditional. The encouragement of a relatively resistant species, e.g., *S. eximia*, at the expense of a very susceptible and abundant species, e.g., *S. parvifolia*, might so favour *eximia* that it would increase to the density at which it becomes a preferred host and create in response a new biological race of *impar*.

Mass-attacks: Attacks on living trees by species normally inhabiting felled timber result from local multiplication in felling-refuse, windfalls, fire killed trees, etc., e.g., **Platypus biformis** in *Pinus longifolia* (p. 341) or **Diacavus furtivus** in *Shorea robusta* (p. 334). Control measures are:— bark abandoned logs and branchwood of over 12 inches girth; spread in the sun slabs and offcuts over 3 inches thick; bark high stumps; avoid injuring poles and trees by ground-fires or controlled burning; fell and dispose of attacked trees similarly. At the same time it is important to diagnose predisposing weakness on the part of the tree, if any (see pp 868-871).

REMEDIAL MEASURES

For timber already attacked by pinhole-borers the remedy is the same as the prevention, i.e., accelerated drying out by sun-heating or kiln seasoning, or, if available, steaming. Conversion into lumber of small dimensions, peeling for veneers, etc., checks further development of tunnels and kills the borers. If green lumber of large dimensions is to be kiln-sterilised, higher temperatures are needed for pinhole-borers than for Lyctus, e.g., 12 hours for temperatures below 140° F.

SCARABAEIDAE, Chafer Beetles, Cockchafer Grubs, p. 348

DAMAGE by species of Scarabaeidae is conveniently considered from two aspects (i) defoliation by chafer beetles and (ii)

injury to seedlings by cockchafer grubs or white grubs. Control measures are general rather than specific as species of different genera work together in association rather than singly.

i, Defoliators

The chafer beetles comprise two groups (a) those flying and defoliating by day, e.g., some *Anomala* p. 353, *Mimela* p. 358, *Oxycetonia* p. 361, *Popillia* p. 361, *Protaetia* p. 362; and (b) those defoliating by night, e.g., *Adoretus*, p 351, some *Anomala* p. 353, *Apogonia* p 354, *Holotrichia* p. 357, *Lachnosterna* p. 358, *Serica* p. 362. If it is essential to protect nursery stock or transplants against day-flying chafers; remedies are available in the form of an arsenical spray with a spreader, p. 861, or Bordeaux mixture, p. 859, which act mainly as repellents and prevent feeding; or by visiting the plants in the cool of the morning to collect the beetles by hand or sweep them into buckets of kerosened water. Against night flying beetles very little can be done as they appear in swarms without warning and the damage is completed before it is noticed; but if the first swarm is detected it is worth while immediately applying a precautionary spray to the nursery beds and adjoining vegetation or putting out light traps. In forests the abundance of species of both groups is determined by the extent of grassland and open thinly stocked crops. The silvicultural measure is maintenance of a closed canopy and shrubby or herbaceous undergrowth; the scarabaeid defoliators of teak [fig. 198, Nos. 4, 6, 13], for example, are largely controlled by the measures adopted for the caterpillar defoliators (see under *Hyblaea*).

ii, Cockchafer Grubs, Cetoniinae, Melolonthinae, Rutelinae, p. 349

Beeson, 1935, ***Ind For.***, LXI, pp. 374-377, Cockchafers and conifers.
Anon, 1937, ***Dept. Agr. Mysore, Calendar***, pp. 41, 45, Control of Holotrichia serrata

Owing to the large number of species of chafer beetles and the diversity of their habits it is not possible to lay down control measures that are universally applicable. It is essential that the species of grub actually responsible for the damage should be indentified as the relative importance of species varies from place to place within a forest division, and often with changes in the soil or with treatment of the soil in one place. The susceptiblity of the plants attacked is another factor; fibrous-rooted and tuberous plants may suffer more than plants with a definite taproot; exotic species may be destroyed where the indigenous plants are immune. Correct determination of the local species of pest is necessary in order to know at what season its eggs are laid and how long the life-cycle lasts. Other factors in dying-off are discussed on p. 873.

Cultural operations

Digging and hand-picking: Whenever seedbeds are prepared

or remade, no matter how temporary the nursery or how simple the method of cultivation, grubs should be removed as a matter of course just as stones, or wood and bark, etc., (which attract termites) should be removed. The grubs should be destroyed, not merely thrown aside. A seedbed 6′ × 3′ may harbour a hundred grubs or more in 18 inches depth of soil, and most of these should easily be found in ordinary digging and pulverising operations. When withered seedlings are noticed in seedbeds it is scarcely worth while digging under and near the dead seedlings; a few grubs may be found but the majority cannot be discovered without serious disturbance to the living seedlings. Injection of soil-poisons is the only remedy (see below).

In taungya or agri-silvicultural operations the principles applied to nurseries must be adapted to the methods of the cultivators in order to prevent grubs passing from field-crops to the trees.

Sowing: Most chafers have annual life-cycles and lay their eggs during the hot weather or at the beginning of the monsoon. Seedbeds prepared or sown at these seasons therefore provide newly turned earth in which chafer beetles readily lay eggs. Sowings made in the autumn, winter or spring are made at a time when the beetles are not on the wing and therefore no eggs are laid in the beds.

In order to protect sowings during the oviposition-period two methods are possible, (a) Prepare the beds a month or so before the swarming time, compact the surface of the soil by watering and patting, and sow seeds in lines with as little disturbance of the surface as possible, or (b) Before the beetles swarm cover the surface and sides of the prepared seedbed with a protective layer of pure sand, gravel, mineral subsoil, crushed charcoal, etc., as available, removing it along the lines when the seeds are sown, and removing the whole layer eventually after the swarming-period of the beetles. Where sulphur can be had cheaply it should be used in preference, dusting it on the beds at the rate of 300 pounds per acre. In permanent nurseries where chafer damage is always expected it may be more convenient to use planks or ¼ inch wire netting frames for the purpose. Permanent beds should be edged with planks as deeply as possible to prevent grubs outside from wandering into the beds. In localities where termites occur treated planks will be required.

Weeding: It is inadvisable to weed or hoe up seedbeds during the flight period of chafer beetles, as disturbance of the surface-soil invites oviposition.

Transplanting: If transplanting is done just before or during the flight-period the empty beds should be protected against oviposition. If the beds are required immediately for resowing, the measures mentioned above should be used; if intended to lie fallow for a period the beds should be watered with crude oil or

kerosene emulsions, p. 858. After the emulsion has been applied it should be followed by a copious application of water in order that the insecticide may penetrate more deeply into the soil.

Trapping: Some species of cetonine and ruteline grubs leave the soil at night and travel over the surface of the ground. Such species may be trapped by constructing V-shaped troughs of boards placed in the ground so that their edges are about an inch below the surface, with the precaution that the boards are overlapped and any cracks or apertures through which the larvae can escape are blocked up. A receptacle, (box, tin or pot) is sunk in the ground at each end of the trough into which larvae crawling along the trough will fall. A simpler scheme is to sink flowerpots or wide-mouthed clay vessels just below the surface at intervals in the pathways between beds. The soil should be packed in a slope around the edge of the pot. These traps need not be emptied frequently as the grubs destroy each other or die from exposure.

Soil-poisoning

For those parts of a nursery not lying fallow but occupied by seedlings or transplants some method of soil-poisoning can be used to kill the grubs in the soil; it is practicable only over small areas and most materials can be used only in dry weather.

C a r b o n d i s u l p h i d e, p. 863, is a most effective remedy for soil-grubs but is expensive, not ordinarily available and needs special storage and handling. Treatment of the soil with commercial carbon disulphide prior to planting appears to have a beneficial effect on the subsequent growth of the plants but the application of a heavy concentration to the roots causes severe injury or death. One lb. per cu. yd. of soil is necessary to ensure destruction of larvae at a soil temperature of 45° F. within 48 hours. Nurseries can be freed by injecting it at the rate of 6 lbs. per 100 sq. ft. when the temperature is above 45° F. and the soil is in the right condition to permit diffusion. For injection the Vermorel Excelsior Soil Injector is usually prescribed; with this instrument fixed doses of the fluid can be discharged; the usual doses are 5 to 15 grammes (1/5 to 1/2 oz.) at the rate of 1 oz per sq. yd. of surface. Alternatively deep holes can be made with a crowbar at about 4 holes to the square yard and the carbon disulphide can be poured in, tamping the hole with earth immediately after.

Carbon disulphide emulsion has a much lower insecticidal action than the pure fluid. It is prepared by mixing 25–30 cc. or 3/4 oz. of carbon disulphide with an equal quantity of coconut oil and adding soap solution made by dissolving 1/4 lb. of bar soap in 1 gall. cold water; the mixture is well stirred. Remove the soil to a depth of 2 inches or so around dying plants and pour in the emulsion until the soil is well soaked and then close the excavation with the turned back soil. The vapour penetrates to

a depth of 9–12 inches and lasts for about a week. No watering or irrigation should be done during this period; but watering a day or two before treatment in dry weather brings the grubs nearer the surface. This remedy does not ordinarily injure healthy roots but promotes the formation of new, vigorous roots and moreover effects a general sterilisation of the soil. Ethylene dichloride emulsion, p. 863, is an alternative.

Calcium cyanide: Make furrows 4 inches deep between the rows of seedlings and sprinkle dust or granules along the bottoms of the furrows at the rate of 2 to 3 oz. per sq. yd. Fill in the furrows with soil.

Naphthalene (p. 864): Young cockchafer grubs can be destroyed in soil by applying naphthalene crystals at the rate of 5 lbs. per cu. yd., provided the soil is moist but not wet, and is free from large lumps, and is left undisturbed for about a week. Naphthalene decomposes in soil in about 1 or 2 weeks; organic matter in the soil hastens decomposition. Mixing naphthalene crystals with the topsoil at the rate of about 1,000 pounds per acre prevents oviposition but does not prevent the beetles from burrowing into the soil.

Acetic acid: Treatment of seedbeds (particularly of conifers) immediately after planting with 0'8 percent acetic acid at the rate of 3/4rs of a quart per square foot of seedbed is effective in preventing grub damage. One or 2 applications is sufficient to destroy a grub infestation in the middle of the growing season. Acetic acid is efficient, inexpensive, readily transportable, harmless to seeds and seedlings and also checks damping-off.

Oryctes rhinoceros, The Coconut Palm Beetle, p. 359.

Cherian M. C. & Anantanaryanan K. P., 1941, *Ind. Farm.*, II, pp. 130-131, pls. 33, 34.
Ghosh C. C., 1940, *Insect pests of Burma*, pp. 186-188.
Dept. Agr., Ceylon, 1936, Leaflet 92, Traps for the black beetle pests of coconut palms —1937, *tit. cit.*, 108, Breeding places of the black beetle of coconuts.

Beetle: A metal rod about $2\frac{1}{2}$ ft. long and 3/8ths inch diameter, bent into a sharp pointed hook at one end and a ring for gripping at the other end, is pushed in the beetle's tunnel and the beetle is hooked out; the cleaned out holes are filled with sand. A skilled climber is necessary. Fermenting oil cake kept in water in an open vessel can be used to attract beetles to ground-level.

Larva: (a) Manure and compost heaps should be raked and spread out at least once every 3 months to destroy the larvae and to allow crows to peck out those overlooked. Ricks of straw are better made on raised drained platforms to avoid fermentation. (b) In Ceylon and Madras green muscardine fungus (*Metarrhizium*, p. 821) which kills the larva and pupa is cultivated and

inoculated into manure and rubbish heaps that are regular breeding-places of the pest. (c) Old palm logs and stumps and logs of softwoods should be destroyed as for *Rhynchophorus ferrugineus*, p. 914.

SCOLYTIDAE, Bark-beetles, Pinhole- and Shothole borers, Seed borers, p. 363.

GENERAL control measures are prescribed for two groups, (i) Bark-beetles and (ii) Pinhole-borers, with examples of special measures for a few species.

i, Bark-beetles.

The North American and European control methods, based on long and extensive practical experience, provide standard principles that are applicable to similar operations in India, whether on a large or small scale.

PREVENTIVE MEASURES

Silvicultural: Regeneration areas under a uniform system, particularly in coniferous forests, are dangerous (p. 836); it is essential that felling-debris should be rendered harmless by proper disposal of slash by the methods given under Remedial Measures.

Departmental burning should be controlled so that bark and lower branches are not scorched or killed (p. 838).

Trees killed or damaged by wind-fall, collapse of girdled trees, erosion, fire, etc., should be discovered and dealt with promptly.

REMEDIAL MEASURES

Barking: For trees which are easily barked and for bark-beetles that are killed by exposure simple barking is effective. It is cheaper and less dangerous than burning if the trees are isolated and small, but is dearer for groups and large trees; it increases the fire hazard. Fell the tree across another felled tree if possible, or raise it on its crown branches so that all attacked places can be completely barked; the fragments of bark are left on the ground to be cleaned by weather and predators. For bark-beetles that complete their life-cycle in thick bark, carry the slabs to an open space and spread them cambium upwards in the sun.

Sun-heating: The solar heat method consists in exposing the log on a N-S line to direct rays of the sun and then turning it after 2 or 3 days so that the shaded sections are heated. A bark temperature of 120°F. is fatal to North American scolytids and this is obtained when the shade temperature is over 85°F. In India most scolytids of thick-barked trees, having short life-cycles, cannot be destroyed by this treatment except in the hot weather generation.

Burning: i, Fell the tree away from young regeneration, uphill or downhill but not across the slope (in order to have better control over the burning). Remove the bark from the attacked

parts of the trunk and pile it along the sides. Lop the crown branches and pile separately. Isolate by means of a fire trace, sweeping the soil-litter towards and under the logs. Burn the logs from the top downhill in dry weather and from below uphill in wet weather; the fire is intended to consume the bark and char the surface of the wood. The logs can be converted or extracted later.

ii, When open spaces are available drag the trunks of several attacked trees to one place and pile them in one stack longitudinally. Use sufficient branchwood for kindling-material and pile the rest separately. Isolate by a wide fire trace. The fire consumes the pile completely. This method is more economical than i and leaves the area clean of slash and logs that would constitute a future fire hazard. Pile-burning develops a very fierce heat and can be done only at a safe distance from the standing crop.

iii, For thin-barked trees or moist situations, or rainy seasons an oil-burning method is used. Fell the tree, cross-cut the top and clear the undergrowth alongside it. Spray a slow-burning fuel oil from a hand pump with a long nozzle along the length of the bole up one side and down the other and set fire to it. Quarter turn the log and treat the remaining bark-space similarly. The bark is scorched and heated enough to kill the borers and the whole operation is quickly completed; in experienced hands it can be used where methods i and ii would be very dangerous.

In North America oil-burning is done on standing trees and is suitable for dead mother-trees over regeneration. A light oil (gravity 32°-34°, Baume flash point 160° F.) is sprayed as high up the bole as possible—a portable pump can reach 30 feet. Fired at the bottom the flames run up the trunk and may also scorch the crown foliage and twigs. The method is economical in labour and 30–50 percent less than other burning methods; $\frac{1}{2}$–1 gall. oil is needed for an average tree.

ii, Ambrosia-beetles, pinhole- and shothole-borers

Measures for the control of scolytid pinhole- and shothole-borers of timber are the same as for similar borers in the Platypodidae, pp. 916–918. Attack by certain types of *Xyleborus* on living seedlings and young trees are discussed below under species, pp. 925, 926.

Blastophagus khasianus, p. 371. Clean up all breeding in felling-refuse, stumps, dead and dying pines (p. 923); fuel billets and branchwood should not be stacked in the forest but exported quickly; not till this is completed is it worth collecting and burning the fallen bored shoots.

Coccotrypes spp., p. 371. Stored seeds should be disinfected by the measures on pp. 894, 895.

Ips p. 375, **Pityogenes** p. 378, **Polygraphus** p. 379, and **Scolytus** spp., p. 384, are controlled by the measures on pp. 923–924.

Sphaerotrypes spp., p. 385; see p. 871.

Stephanoderes hampei, The Coffee Berry-borer, p. 387.

Dept. Agr., *Ceylon*, 1937, Leaflet 103, The coffee berry-borer, pl.

In areas of slight infestation collect all bored green, ripening and ripe berries on the coffee bush and all fallen berries during one morning at intervals of at least 2 weeks. Destroy the berries by burning or by boiling for 5 minutes enclosed in a cloth bag in a vessel of water. In areas of heavy infestation collect from low bushes the whole crop of berries and flowers and fallen berries and burn the lot. High unpruned bushes should be cut back below the lowest fruiting branch; burn prunings and fallen berries the same day. Inspect the next crop at fortnightly intervals and destroy attacked berries as above.

Thamnurgides cardamomi, p. 389. Where cardamom is cultivated in evergreen forest containing trees which are alternative food-plants of the borer, their fallen fruits should be regularly collected and destroyed. *Thamnurgides* spp. in stored seeds are controlled by the measures on pp. 894, 895.

Webbia, Xyleboricus & Xyleborus spp., p. 391, are controlled by the measures on pp. 916–918.

Xyleborus fornicatus, The Shothole-borer of Tea, p. 395.

Speyer E. R., 1919, *Dept. Agr. Ceylon*, *Bull.* No. 43, Treatment of prunings on infested estates. — *tit. cit.*, No. 44, A control pruning scheme and its practical modification. — 1922, *tit. cit.*, No. 60, Damage caused to the teabush.

Jepson F. P., 1922, *tit. cit.*, No. 54, The treatment of buried prunings on shothole borer infested estates.

Jepson F. P. and Gadd C. H., 1925, *tit. cit.*, No. ‹2, The control of shothole borer of tea.

The control measures used for the shothole-borer of tea in Ceylon are instructive as to the practical possibilities of similar methods for forest trees.

C h e m i c a l: The application of poisonous paints to kill borers in the frame of the tea bush after pruning is too expensive to be profitably employed.

M e c h a n i c a l: Scorching the bushes and the use of light-traps are unsatisfactory.

Proper disposal of the prunings of bushes is essential to ensure the death of the borers in the attacked branches. If prunings are left on the ground in the dry season, the mature pupae and adults emerge successfully and in the wet season the late larval stages, pupae and beetles do so. If prunings are buried at depths down to 18 inches, the broods develop normally for a month and adult beetles are still alive after 2 months; these beetles burrow their way up through 18 inches of soil and escape. If the prunings are burnt all insects are killed but the loss of manurial constituents to the soil in general bulk and in nitrogen, even though potash and phosphoric acid are returned in the ash, is too great to sanction burning as a remedy. Burying the prunings with insecticides

that will kill the borer is too expensive. The practical compromise is to strip off the leaves and twigs (to pencil thickness) and bury them, while the larger branchwood is burned and the ashes broadcast. Additional prunings done in the period between the cultural prunings have been tried and abandoned. As about ¼ of the total open galleries present on a bush are in the collar and lower part of the frame it is impossible to eliminate all borers without mutilating the bushes.

Cultural: The application of a general manure mixture (nitrogen, phosphoric acid, potash) increases the vigour of growth of tea bushes, promotes more rapid healing of exit-holes of the borer, reduces the population of borers per bush and reduces the incidence of subsequent attack (p. 815). To maintain these advantages manuring should be annual.

The utility of alternative food-plants as traps, e.g., by interplanting tea with *Ricinus communis*, is negligible owing to the fact that *X. fornicatus* persists as a biological race in tea (p. 814).

Xyleborus morigerus & X. morstatti, p. 400. The conditions under which shoot-borers of this type attack living plants need further study. In Java *morigerus* affects mahogany seedlings under shade when height growth is slow or has ceased; it fails to establish in thicker stems and in plants in the open. In coffee bushes the primary cause of mortality of twigs is assigned to other causes than direct *Xyleborus* attack; the percentage of infested twigs is higher in bushes with one stem than in those with two stems. Destruction of infested twigs is usually advised for coffee, etc., but this has little effect for tree seedlings in which breeding is not continuous through the year and reinfection is derived from other food-plants.

TENEBRIONIDAE, p. 406.

Gonocephalum spp., p. 407. Flood the ground or keep the earth round the plants quite moist and collect the beetles and larvae which appear above ground as a consequence. Seedbeds may be watered with cabolineum or crude oil emulsion 1 in 500, p. 858. Powdered naphthalene may be mixed with soil and put around the plants, p. 864. In taungya or nurseries heaps of fallen leaves should be examined and if found to be breeding-centres should be destroyed, or used as traps Better traps are heaps of decaying straw of paddy, ragi, etc. *(Eleusine, Panicum)*, soaked long in water; weeds pulled up by the roots are very attractive. Spread the baits an hour or so before sunset and collect the beetles soon after nightfall when they come out and feed. Where inspection cannot be done, chopped grass soaked in a solution of sodium arsenate 1 lb., jaggery or molasses 8 lbs., water 10 galls. is spread over the ground in the evening.

Coleman L. C. and Kunhikannan K., 1938, *Dept. Agr. Mysore, Bull.*, No. 5, Ground beetles attacking crops in Mysore.

CHLOROPIDAE, p. 422.

Siphunculina funicola, The Eye-fly. Clean up breeding-places, i.e., cattle dung, raw manure, decaying vegetation in house drains. Hang strings inside rooms and crush the flies clustered on them with a duster, or spray with kerosene, and replace clean strings.

CULICIDAE, Mosquitoes, p. 422.

IN carrying-out an anti-mosquito campaign the objective must be defined, i.e., it is either total elimination of malaria carrying species—an anti-malaria measure—or it is general reduction of all nuisance species; in the former case the measures designed for the species of *Anopheles* concerned should be worked out in consultation with the Malaria Bureau; in the latter case treatment of larval breeding-places on general lines with nets, sprays and repellents for the adult mosquitoes is sufficient. An example of a local mosquito fauna is that of the Forest Research Institute which consists of 6 species of *Anopheles*, one of which is an important malaria-carrier, and 12 species of culicines, all breeding in artificial or man-made accumulations of water on an area of less than one sq. mile.

LITERATURE ON MOSQUITO CONTROL: see also pp 426, 428.

Covell G., 1935, *Health Bull* No. 11, *Malaria Bureau* No. 3, Anti-mosquito measures with special reference to India.

Christophers S. R., Sinton J. A. and Covell G., 1936, *lit. cit.*, No. 14 and No. 6, How to do a malaria survey.

Sinton J. A., 1935, *lit. cit.*, No. 13 and No. 5, Instructions for collecting and forwarding mosquitoes.

MEASURES AGAINST ADULT MOSQUITOES

Repellents and sprays suitable for mosquitoes are given on pp. 859, 860. For fumigation of closed rooms vaporise liquid cresol (4–5 oz. per 1,000 cuft.) in a large tin vessel over a charcoal angethi or an oil stove; the vaporisation takes about ½ an hour and after removing the stove keep the room closed for 2 hours; or ignite a cowdung cake and when it is half burnt pour the cresol on. Mosquito netting should be of 25–26 mesh, woven of 30/s cotton, i.e., the sum of the holes counted along a line of the warp and a line of the bobbin in one square inch is 25 or 26 and the cotton goes 30 × 840 yards to the lb.

A simple trap is a large earthenware chattie containing a handful of moist sand and placed in a dark corner; in the morning close the mouth with a ball of cloth and shake vigorously to kill the mosquitoes.

MEASURES AGAINST LARVAE, ETC.

Oil: Oiling water kills the eggs, pupae and larvae, and kills culicines as well as anophelines. Its disadvantages are that oil will not easily penetrate a barrier of grass or floating vegetation, the oil film is broken up by wind and carried to one side of a sheet of water, during rainy periods the value of oiling is decreased, oil is heavy to transport and liable to be stolen by employees; it renders water unfit for domestic purposes and kills fish and other aquatic natural enemies of mosquitoes, oiled water does not act

as a trap but deters mosquitoes from laying eggs and disperses them in search of more suitable unoiled water.

The oils that may be used are kerosene, crude fuel oil, light engine fuel oil waste motor oil, liquid paraffin and petrol or mixtures in which these oils are the main ingredients. With high temperatures a thick oil is best; in the presence of vegetation a good spreading oil is needed; on still water a heavy non-toxic oil can be used; on moving water a thin layer of rapidly spreading oil with a high toxicity is needed. The spreading power of oil does not depend on its viscosity, e.g., a thin kerosene oil does not necessarily spread better than a thick fuel oil. The addition of 1–2 percent of cresol, phenol, turpentine or castor oil increases the spreading power and penetration on water covered with dead organic matter or vegetation. The presence of dust or grease or soap prevents oil from spreading (Covell). Kerosene is largely used because it is generally available. A more economical and efficient mixture is fuel oil or heavy diesel oil 2 parts, light diesel oil 10 parts, kerosene or cresol 1 part.

Oil is applied by means of a spraying machine, soaked cloth bundles, drip cans, etc., at the rate of 1/2 oz. per sq. yd. or 15 galls. per acre of water-surface.

Sprayer: A hand or bucket sprayer is suitable, p. 866, with a nozzle delivering a fine mist in a cone spray of about 18 ins. diameter at 4 ft. distance in front of it. Filter the oil into the sprayer through a sieve and clean the apparatus daily with kerosene, particularly nozzle jets, joints and valves.

Cloth bundles: Balls or bundles may be made of cotton-waste, sacking, tow, cloth, etc., soaked in oil, tied with rope and attached to a sinker weight or to a float and placed in tanks or water-channels. The oil gradually oozes out of the cloths and rises to the surface of the water, renewing the film. The oiled cloth should be taken out, dried and reoiled after 7–10 days. Large size sacking-bundles as big as a pillow, say 28″×16″, will soak up about 2 gallons of oil at first and about 1 gallon when resoaked, and will last in operation about 3 months. This method is useful in drains and canals with intermittent and irregular flow through culverts and siphons where water stagnates.

Mop: A mop of cloth at the end of a long stick which can be dipped in oil and whirled or swabbed over the water is useful and economical for drains, channels and small surfaces.

Drip cans: A metal container such as a large tin or bucket is prepared by driving a nail through the bottom and wrapping wool or cloth round the head of the nail; or a splinter of wood and a lamp wick may be used to plug the hole. Arrange the plugs to give 10–20 drops per minute for a moving water-surface 1 foot wide.

Paris green: As a mosquito larvicide the advantages of Paris green are its low cost, high toxicity for anopheline larvae, portability, and ease of

distribution by wind; it has no ill effects on animals, fish and other natural enemies of the larvae, or on aquatic vegetation and does not render the treated water unfit for domestic purposes; it does not prevent mosquitoes from depositing their eggs and can be used equally effectively in fresh or brackish waters. Its disadvantages are that it has no lethal effect on the eggs and pupae of mosquitoes, or on the very young larvae of anophelines, and no effect on culicine larvae, it requires special apparatus for distribution, screening and mixing, its use requires constant supervision and proper application is more difficult to check up than in the case of oil

The chief use for Paris green is in places where, for some reason or other, oil cannot be applied, e.g., on water used for domestic purposes, irrigation, ornamental purposes; or water that cannot easily be treated except by a dust cloud carried by wind. In the quantities in which it is used as a larvicide Paris green is harmless to man and to domestic animals who may drink the treated water. Nevertheless it is advisable that workers distributing the larvicide should keep to the windward of the dust-cloud and they should change outer clothing and wash hands and feet after work. (p. 862).

i. For dusting large areas, a $2\frac{1}{2}$ to 5 percent dilution of Paris green in slaked lime or powdered soapstone (or soft stone) applied by means of a rotary blower, $\frac{1}{2}$ to 1 lb. of Paris green to the acre.

ii. For treating narrow irrigation channels, ditches, etc., a 1 percent dilution of Paris green in road-dust or fine sand, applied by hand from a haversack (Covell, 1935).

Diluent: For dusting an extensive area of swamp or lake the diluent should be light and readily carried by wind for a long distance e.g., soapstone or soft stone powder, and slaked lime. Softstone powder (soapstone) costs from Rs. 30–65 (Calcutta) per ton. Slaked lime should be prepared from good quality quicklime and slaking should not be carried to completion. For dusting small streams, ditches, irrigation channels, small tanks and ponds of water a heavier diluent should be used as being more manageable on a small area in a high wind, e.g., alluvial earth, road dust, ashes.

Screening: The diluent must be screened or sieved to remove the larger particles. A simple screener consists of a rectangular wooden tray about 2 ft. × $1\frac{1}{2}$ ft., with a fine wire gauze bottom, on the top of which fits a second tray with a bottom of coarse mesh wire gauze. The screener is suspended from the roof by cords attached to its four corners, and is agitated by hand, after the manner of sifting grain.

Application: The mixture is thrown by hand after the manner of sowing grain from a bag resting on the hip and suspended from the opposite shoulder. This is probably the best way of applying Paris green to small areas of water, irrigation channels, etc. A rotary blower is effective in skilled hands and useful for dealing with large areas.

Frequency: As a general rule Paris green should be

applied once a week, but when the larval development is unusually rapid the interval should be reduced to 5 or 6 days. At each application the larvicide is used at the rate of ½ to 1 lb. of Paris green per acre of water-surface.

ITONIDIDAE, Gall-midges, p. 432

No practical methods of control of forest gall-midges are known. Teak varies in its susceptibility to attack by gall-midges, p. 435, in different parts of its habitat and this characteristic is inherited, p. 872.

MUSCIDAE, Housefiies, p. 436

MEASURES AGAINST ADULT FLIES

A fly spray formula is given on p. 860. Sticky fly papers or strings are made from the rosin-castor oil formula on p. 860, applied to glazed paper. For fumigation of closed rooms see p. 927.

Fly-poisons are: i, Formalin 1 teaspoonful in a saucer of milk and alkaline water with a little sugar and a piece of bread. ii, Sodium arsenite 2-3 oz., sugar 3 lbs., water 4 galls; this is best used out of doors on a roller-towel trap which consists of an endless band of cloth on an upright frame, and dipping into the poison solution in a container, and kept moist by rotation at intervals.

There are many types of fly-traps for indoor and outdoor use made of wire gauze, working on the principle of entrance through a slit at the base with an angular baffle and overhead light to prevent exit; they are baited with sweet or putrescent substances which are usually poisoned.

MEASURES AGAINST LARVAE, ETC.

The larval breeding-places are given on pp. 436, 437; the most important are human excrement and horse or cattle dung.

In any areas where the forest officer can enforce proper sanitation (e.g., resthouses, subordinates' quarters, depots, labour camps, forest villages) the breeding of flies in human excrement is preventable. Permanent deep pit-latrines, enclosed and darkened, are ordinarily fly-proof. Temporary shallow trench-latrines in the open are prolific breeding-sites; covering the deposits with earth is no remedy as flies can emerge through 2 feet of soil; the soil in a closed trench must be saturated with kerosene (1 gall. to 2 sq. yd.) or must be sealed with a layer of newspaper or sacking extending a foot beyond the trench all round, turned down at the edges for 6 inches and covered above with 4 inches of soil.

For stable manure and vegetable refuse (a) in the dry season spread out each day's output in a thin layer on the ground in order to be desiccated quickly by sun and wind; or (b) in the wet season pack it in a compact heap on a hardened, oiled, level floor,

beating and pressing the dung firmly into a solid block; fermentation is induced, the temperature rising to 160–170° F., which is considerably above that needed to kill larvae and pupae; the daily additions of dung are buried 6 inches deep in the dump and compacted. (c) An alternative to these methods in a permanently inhabited settlement is the installation of incinerators.

PSYCHODIDAE & SIMULIIDAE, p. 438

For repellents against sandflies and potu flies see p. 859, 860.

FORMICIDAE, Ants, p. 499

ANTS IN BUILDINGS

TEMPORARY relief is obtainable by spraying with fly spray, dusting with sodium fluoride powder or pyrethrum or flea powder. A sponge or loofah saturated in sugar solution attracts small ants; by dropping the sponge into boiling water large numbers are killed and the sponge can be put out again. If the holes or cracks from which ants emerge or by which they enter can be located in the masonry or woodwork of buildings, pour into the hole a little carbon disulphide, orthodichlorobenzene or petrol, and close the hole with putty or cement or clay.

Poison baits

Thallium sulphate: The best poison bait for small ants is water 1 pint, sugar 1 lb., honey 3 oz., and thallium sulphate 27 grains. The ingredients are thoroughly mixed together and brought almost to boiling point, care being taken not to breathe the vapours when stirring the heated mixture. Thallium sulphate is a dangerous poison.

Barber bait: Heat 10 pints water and dissolve in it 1/4 oz. tartaric acid crystallised, 1/4 oz. benzoate of soda and 12 lbs. sugar. Boil this solution slowly for half an hour adding enough water to make up for loss by evaporation. In a separate container dissolve 3/4 oz. of arsenite of soda in 1 pint of hot water. Mix the two solutions together and to the final mixture add 2 lbs. honey. Stir thoroughly until all ingredients are mixed. The result is a thin clear slightly yellowish syrup.

Simpler poison baits are: i, Dissolve 4 oz. of sugar in a quart of water and stir in 1/2 oz. of tartar emetic. ii, Dissolve 1/2 lb. sugar in 1 pint of hot water and add 1/7 oz. (62·5 grains) of sodium arsenate; bring to a slow boil and strain. A weak solution does not impair the attractiveness of the syrup and the workers do not die before they have returned to the nest and have distributed some of the poison to other members of the colony.

For ants that do not eat sweet substances but take meat and fat and grease, a poisoned bait can be prepared by working small quantities of tartar emetic into the meat.

Bait containers: Punch 2 holes about 1/2 inch diameter on

opposite sides near the bottom of a cylindrical or boxshaped tin and tie a piece of oiled paper over the top or use the original lid. The poison is poured on to crumpled strips of blotting paper or absorbent cloth. The poisoned ants die in the nest or in secluded places.

Barriers: Ants can be kept off tables, shelves, cupboards, etc. and other moveable legged furniture by placing the legs in shallow dishes, pots or other receptacles which are filled with kerosene or a layer of oil on water. Inspect the dishes to keep the liquid surface clean of dead ants and rubbish.

Ant tapes fastened round the legs of furniture are used where kerosene containers are undesirable. A tape is prepared by boiling it for a short time in a saturated solution of corrosive sublimate (bichloride of mercury) and hanging it up to dry.

Bands of loose cotton or cotton wool can be gummed or tied round the legs of furniture. Renewal is necessary when the band loses its fluffiness and gets compressed.

ANTS OUT-OF-DOORS

Ants' nests may be fumigated: (a) Make a vertical hole about a foot deep with a crowbar or stake in the central opening of the nest and pour in about ½ pint of carbon disulphide and immediately close the hole with earth, rammed down. Treat when the nests are occupied, i.e., early morning. (b) Make a hole as above and introduce from 1 to 4 oz. of calcium cyanide, granulated (Cyanogas), and close the hole and all other traffic-holes or apertures in the nest. Treat at any time except in the rainy season or when the soil is damp. The ants die in large numbers outside the nest.

VESPIDAE, Wasps and Hornets, p. 520

Polistes hebraeus: Damage to books and papers during the nest-building season is preventable by spraying with a solution of napthalene in benzene or petrol and by destroying the nests.

Vespa auraria: Congregations of wasps on ceiling, walls, etc. can be driven away by spraying or brushing with napthalene 1 part, lysol 1 part, kerosene 4 parts; smoking or flaming is less effective.

V. basalis: Spray the attacked tree with a strong solution of lead arsenate and extract of neem leaves, p. 862; locate and destroy the nest. **V. cincta**: Spray the nest with kerosene and burn during the night.

XYLOCOPIDAE, Carpenter Bees, p. 520

Xylocopa spp.: The bees can be driven away from rooms and verandahs by painting the attacked woodwork with creosote or fuel oil thinned with kerosene; if dichlorobenzene can be obtained it should be added to the mixture until its odour predominates; the tunnels should be filled or well saturated with the

mixture. The tunnels will probably be tenanted again by bees in subsequent seasons if they are left open, hence it is worth while filling them up with cement or wooden plugs or any convenient substance other than mud, and creosoting or linseed oiling the whole woodwork regularly each year. Tarring has no deterrent effect after the tar has dried. A thick coating of whitewash will protect roof-rafters and posts and if renewed twice a year will act as a permanent deterrent.

ISOPTERA, Termites, White Ants, p. 524

CONTROL measures for termites are discussed in 3 sections—i, Protection of buildings, ii, Stored timber and timber structures and iii, Living trees, with preventive and remedial measures in each section. For literature see end of section iii.

1, PROTECTION OF BUILDINGS

Termites which invade buildings and damage the woodwork therein may be assigned to two distinct groups of species depending on the normal position of the nest (p. 529), either (a) below ground in the soil (ground-dwelling termites), or (b) above ground in masonry or woodwork (dry wood termites). Species which nest below ground ordinarily enter buildings as workers and soldiers through the foundations and walls from the soil. The non-subterranean species ordinarily arrive as winged sexual forms and start new colonies direct from the egg in suitable crevices or cavities in the walls or timbers.

The main principles which must be applied to prevent damage to structures made wholly or partly of wood are:—

1. Eliminate and prevent the breeding and colonisation of termites in the vicinity of the structure or material by removing all sources of infestation.
2. Make the structure or material inaccessible to termites by means of impassable barriers formed by special constructional designs.
3. Use wood which is undesirable to termites as food, i.e., termite-resistant timber, or which is unavailable to termites as food, i.e., timber treated with preservatives.

1 a, PREVENTIVE MEASURES

Cleaning up the building site

The sites for resthouses, quarters for the divisional forest staff, sheds, depots, etc., which are selected in recently cleared forest land or in waste land should be cleaned of all breeding-places. Not only in the foundations and plinth area of the building, but also in the compound and immediate neighbourhood termite nests should be destroyed, and decaying logs, dead or living stumps and buried roots should be removed and destroyed. This cleaning up should be done as thoroughly as the importance of the building demands.

Destruction of mounds and nests: To destroy the nests of moundbuilders (p. 532) it is not sufficient to break up structures above ground and kill the queens as new queens are produced to replace those destroyed, p. 527; each colony should be killed off with poisons or fumigants.

Poisons: White arsenic is an effective and very toxic material used at the rate of $\frac{1}{4}$ oz. to $\frac{1}{2}$ oz. (1 to 2 level teaspoons) for each mound. Remove the above-ground parts of the mound and expose the underground cavities; fill these with the arsenic powder mixed with dry alluvial dust or fine sand and cover the surface with a layer of soil. If a large area containing many mounds is to be treated and expenditure on labour in breaking up the mounds is to be avoided, make a tunnel with crowbar or soil augur in each mound from one side to the centre and blow the pure white arsenic powder unmixed with dust into the application hole by means of a blower made from a rubber bulb fitted with a long nozzle (e.g., a motor horn). Work in dry weather and plug the holes after treatment. The colonies of termites in the mound will be killed off in one or two months.

Fumigants: (p. 863). A mixture of 1 part creosote to 3 parts kerosene or petrol; carbon disulphide or carbon disulphide emulsion; ortho-dichlorobenze (liquid or crystal); diphenylamine. These liquids are poured in small doses and the excavation covered over with soil, and all apertures from which gases may escape are plugged with mud. Diphenylamine remains effective at low concentrations for long periods (e.g., for 7 months at 1 part in 8,000 of soil).

Petrol alone is very effective if used as follows: Ascertain the diameter of the base of the mound and level it off. Drill holes in the levelled area at the rate of one hole for every 6 inches of diameter and 1 oz. petrol should be injected in each hole; e.g., a mound 18 ins. diameter requires 3 holes, and a mound 6 ft. diameter requires 12 holes and 12 ounces of petrol. The holes should be uniformly distributed and about 12 inches deep. The easiest method of injection is with a crowbar and a long necked funnel (Hutson).

Calcium cyanide (p. 863) in powder or granular form can be applied with a large spoon, a hand-blower or a foot-pump or a Cyanogas dusting-pump. From 3 oz. to 1 lb of calcium cyanide is required for a mound. Specially designed fumigating pumps, e.g., the Four Oaks, or the Blue Mysto, or the Universal White Ant Exterminators, exist for forcing the fumes of heated sulphur and white arsenic into the nests of termites; the heating is done by a charcoal brazier. Where extensive building operations are contemplated in a bad whiteant locality it is worth while purchasing special apparatus of this type. Full directions for use are supplied with the pumps.

Termites that do not build mounds: Where the local species of termites do not build conspicuous mounds but inhabit diffuse nests and tunnels underground, p. 530, it is not possible to destroy their nests extensively unless exit-holes are located when swarming occurs. Soaking the soil of the foundation-trenches and floor-spaces, or near any tree the roots of which are severed

in making boundary or drainage trenches or levelling operations, etc., with a 20 percent solution of zinc chloride or copper sulphate provides only a temporary benefit and it is wiser to rely on termite proofing the walling and woodwork. After the building has been erected fresh nests or mounds may be formed in the vicinity by the arrival of colonies from far distant nests through pre existing tunnels, or by the establishment of new females and males after swarming These should be promptly dealt with as described above and not be allowed to develop unchecked.

Provide adequate drainage of the site and ample ventilation of the substructure of the building

Construction of termite-proof buildings

The precautions that can be taken in order to construct a termite proof building depend on the type of building to be erected.

Incompletely protected buildings: There are some types of buildings which are impossible to protect, viz. —

Buildings with earth or cowdung floors or mud walls
Walls of sundried brick or burnt brick in mud-mortar
Walls of stone or laterite in mud-mortar
Walls of brick or stone in lime-mortar with earth filling
Walls of untreated wattle or lath and daub, or bamboo matting and daub

Partial protection can be obtained in such buildings by using resistant or treated timber for the framing, the walls, and the roof, without special flooring or other anti termite devices total protection of stored material cannot be guaranteed. Information on the design and construction of walls of treated lath and plaster, or treated boards, planking, and plywood will be found in *Treated Wood for Walls and Ceilings*, 1936, Wood is good, No. 23, Timber Development Section, Forest Research Institute.

Of the buildings that can be made termite proof (apart from the nature of the woodwork, brickwork or masonry in the walls) there are two main types, having (a) concrete floors in contact with the ground, and (b) floors raised above ground by masonry pillars or wooden posts.

Isolation of timber: After the sterilisation of the building site the most important factor in protection is **the isolation or insulation of timber from contact with earth.** "Complete insulation from the ground of all untreated woodwork of buildings is the only effective permanent remedy against attack by subterranean termites, and the only relief from their presence. These insects must maintain contact with the ground to obtain the moisture necessary for their existance. When contact with their moisture supply in the earth is cut off, the subterranean insects in the damaged wood, no matter how numerous, soon dry up and die". (Snyder) No untreated timber should be allowed in contact with the ground, even when treated timber is used there should be a layer of dense concrete at least on inch thick between any timber, such as doorsills, flooring joists and planks, posts, steps, etc, and the rougher concrete foundation. Beams should not be completely

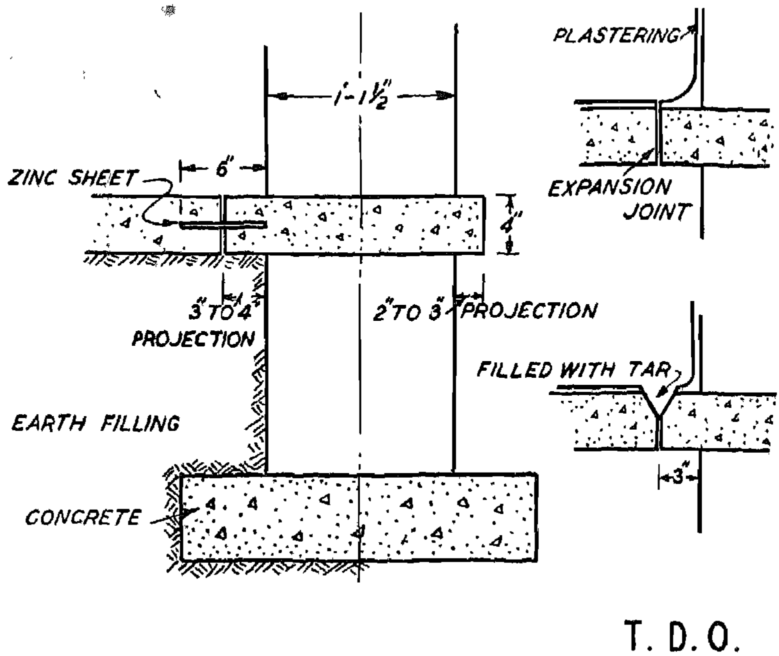

Fig. 200. Anti-termite joints between a concrete floor and the wall; see text

surrounded with mortar or brick, but should have an empty space round them sufficient for the circulation of air, i.e., boxed not sealed.

Concrete floors

The concrete floor, which is ideal from the standpoint of the termite hazard, is one laid down on a naturally solid, not filled-in, foundation in a continuous course, unbroken by settlement joints and firmly united to the foundation walls with a concave "sanitary" cement skirting. Such an ideal foundation is rarely available, except possibly on laterite and certain alluvial earths.

The ordinary forest building has a raised plinth with a floor constructed above filled-in earth, often on an uneven site, and the filling is not always uniformly consolidated. A 4-inch layer of sand immediately below the concrete floor, as prescribed by some Public Works Departments has the same defect. In the subsequent settlement the concrete cracks, either at the junction with the foundation wall, or within the floor space, wherever the greater weakness occurs.

To obtain satisfactory results with a concrete floor it is very necessary that the filled-in earth should be properly consolidated.

The earth, or other material used for filling, should be laid in level layers and each layer should be well rammed. It is the general practice to dump in the filling material unevenly and to finish off with one final and somewhat superficial ramming; this is a bad practice and should be avoided. Where a hard wearing surface is not required, as for a normal floor, one course of concrete, if laid on well consolidated foundations, should be sufficient. Where the floor is laid in 2 courses the lower course should be well laid and sufficiently cured in order to prevent cracking. By laying the concrete in alternate squares or sections, trouble at the joints will be reduced to the minimum. Laying an asphalt course over the lower concrete course is expensive, but it would aid as an extra deterrent to the passage of termites. The sections of the upper course could be laid so that they break joint with the sections of the lower course.

A well laid floor requires no settlement-joints; normal atmospheric conditions do not appear to make expansion-joints necessary. In a 2-course concrete floor the upper course at least could be monolithic. The construction of the floor near to walls needs special design and care. Three alternative methods of jointing are shown in fig. 200. The termite-barrier or damp-proof course in the wall is shown as a solid concrete layer 4 inches thick and projecting 2 to 4 inches on the outer and inner faces. The joint between this course and the concrete floor may be a sheet metal strip [fig. 200, full central drawing], or an expansion joint with a concave 'sanitary' cement plastering of the wall-floor corner [fig. 200, top right], or a V-shaped gutter which is filled with plastic coaltar pitch [fig. 200, bottom right]. A floor made to this specification of properly mixed and properly cured concrete should not crack and should be impervious to termites. Correct preparation and curing of the concrete is the most essential part of the specification; in practice this means constant supervision of the building operations is essential.

A floor laid in independent sections with settlement-joints in anticipation of subsequent readjustment is not recommended. The settlement-joints are usually filled later with cement or mortar or asphalt, and in practice these also crack as does the cement surface rendered over the concrete. Termites are able to work through these cracks and through sand and through rough porous concrete; the only satisfactory treatment for settlement or contraction is frequent repointing or grouting with cement or plastic coaltar pitch as new cracks are formed. Constructional designs that would prevent this remedial treatment of cracks involve the use either of reinforced concrete, or of metal bonding-strips let in across the settlement-joints [as in fig. 200], or more complicated specifications beyond the possibilities of most forest departmental buildings.

Wooden floors on concrete: Flooring laid on joists on concrete, as also wooden block or parquet-flooring laid on concrete

are unsafe unless resting on at least 1 inch of dense concrete without cracks or joints. Unless this can be assured pressure impregnated timber must be used.

Foundation walls

To be termite-proof foundation walls should be made entirely of stone or brick in lime-mortar or cement-mortar, or of solid concrete and, if properly constructed and reinforced, are actually impermeable to termites. In practice there are points of weakness, especially in the mortar joints on the side faces, through which the insects can gain an entrance and there is usually insufficient mortar in the interior of the wall. Inferior lime-mortar disintegrates in the course of time and allows termites to find passages between bricks and stones. The parts of such walls which are in contact with earth should be faced or pointed with cement, i.e., the pointing should be done from the base of the walls within the foundation trenches.

Termite barriers

Concrete course or damp-proof course: Architects and engineers in India rely mainly on the use of a damp-proof course of concrete, slate and/or a water-proof substance such as asphalt or pitch to isolate the superstructure from the foundations. This takes the form of a continuous concrete course, 3 or 4 inches thick (sometimes projecting 2-4 inches outwards from the wall on each side), placed on all external and internal walls between the foundation and the superstructure at the level of the top of the floor [fig. 200]. Such a barrier serves also as a damp-proof course if water-proofing materials are incorporated in the concrete or spread on its upper surface. So long as the barrier is perfectly constructed and is not broken after construction in order to add bath-room waste pipes, door-sills, or to bond additional walls, etc., it functions effectively and permanently as a barrier to termites ascending within the walls; but it does not check the progress of termites working on the face of the wall under runways or sheets of mud.

Termite shield: In the United States of America and in several other countries the standard practice (or at least the standard recommendation) for an impassable barrier is the metal termite shield. This is used in the form of a 6 inch strip of noncorroding metal (such as copper, or zinc, or an alloy composed of 28 percent of copper, 67 percent of nickel, and 5 percent of iron, manganese, and silicon), firmly inserted in the surface of the masonry, or between the foundation and the wood, extending horizontally at least 2 inches from the face of the foundation with the projecting edge bent downward for another 2 inches at an angle of 45°. The corners of the shield should be soldered or crimped. In masonry buildings this shield can be inserted in the masonry at a height at least 18 inches above the ground. (Snyder's specification) [fig. 201]. The metal termite shield by its narrow edge and slope provides a practically complete obstacle to termites that construct

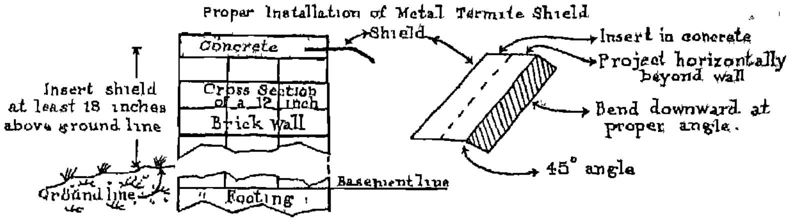

Fig. 201, Metal termite shield ; Snyder's specification.

surface shelter-tubes. They may be able to build tubes downwards over metal shields but not upwards. It is of little use unless complete around the top of the masonry foundation, including the internal walls, dwarf walls, pillars, piers, etc., on both the inside and outside surfaces. It may be superfluous on the outer face of external walls, if the building is under constant inspection and runways are removed when seen—a stipulation that is difficult to enforce in forest rest-houses and quarters. Its value is obviously nullified if creepers or woody climbers are allowed to grow up the walls and bridge the barrier.

Termite gutter: *Another form of termite barrier can be* used in wooden buildings carried on brickwork, or concrete piers or wooden posts. A channel is cut around the base of each post in the concrete surface supporting it which is filled with oil and kept regularly oiled. Its use is limited to posts that are readily accessible (Desch, 1940, figs. 1, 4).

The principle of complete insulation of the superstructure from the foundations and the ground is one that should be fully understood by the contractor and workmen, and should be borne in mind when breaches are made in the barrier at later stages in construction or in subsequent work on the building after its erection. Such breaches should be repaired with dense concrete or cement and impervious junctions should be made between broken parts of the metal shield and between the shield and the masonry.

Raised floors

Buildings with the floors raised above ground-level are roughly of two classes (a) frame buildings supported on pillars or dwarf walls of brick or masonry, and (b) timber buildings constructed wholly of timber.

Timber buildings supported on vertical posts have the posts sunk deep in the earth, or, more rarely, based on masonry foundations. The most satisfactory design bases the post on a concrete block with a cement mortar sleeve to above ground-level, where a termite gutter for oil is provided. For this purpose only posts of resistant heartwood or impregnated with a preservative should be used. For buildings constructed in the forest, where

no tank is avilable, butt-treatment normally gives sufficient protection (p. 947). But if the local termites are species that work over the oiled or poisoned surfaces in tunnels of earth and excrement it is necessary to interpose on each of the posts, between ground and floor, a termite barrier in the form of a metal collar, i.e., a strip of non-corroding metal or galvanised iron turned over with a projection of 2 inches and bent down at an angle. Posts ending short at floor level should be entirely capped with a shield shaped like an inverted square tray or pan [fig. 202, below]. The shield is fixed to the post with a nail, the nail head being soldered to close any aperture around it. A bearer resting on a shield is fixed by means of bent metal strapping soldered to the surface of the shield. The side flaps of the strapping are bent and nailed against the sides of the bearer [fig. 202, below, right]. Side posts that continue past the floor and support the roof must be fitted with a collar. As circular collars are difficult to fit this necessitates the use of squared posts or the fashioning of a squared or hexagonal head to a rough hewn post. The metal strips should be soldered where the angles meet, and embedded in asphalt where nailed to wood. When posts are supported on concrete, brick or stone piers carried up above ground-level they should rest on the piers (not built in) and should be anchored by metal dowels let in, or by metal straps [fig. 202].

Frame buildings with the floor-frame supported on pillars or dwarf walls of masonry or brickwork may be protected by capping each of the supporting pillars or the skirting wall with a metal termite shield, as illustrated in figs. 201, 202; the complete cap is suitable for pillars of small bearing surface [fig. 202, below]; the continuous strip is suitable for lengths of walling and may be inserted at the top of a stone wall or in one of the courses in a brick wall [fig. 202, above]. The frame or floor joists should have a clearance of not less than 18 inches between their lower faces and the surface of the ground beneath. Openings should be provided in the external walls of the foundations for efficient ventilation underneath the floors, and the openings should be screened with 20 mesh to the inch wire gauze.

Staircases and steps leading from the ground-level to the floors of timber or frame-buildings should not be solid but should rest on concrete or brick foundations and should either (a) be protected in the same way as the foundation walls with a termite-barrier and by impregnation of wood, or (b) be separated from the building by a gap of 2 inches.

Use of resistant timber

Timber may be naturally resistant to termite attack not because of its hardness but because of the presence of lignin or of hot-water extractives which may be oleo-resins, essential oils, tannin, or other inclusions. The resistance of a particular kind of timber may be known from its general reputation, or from the results of

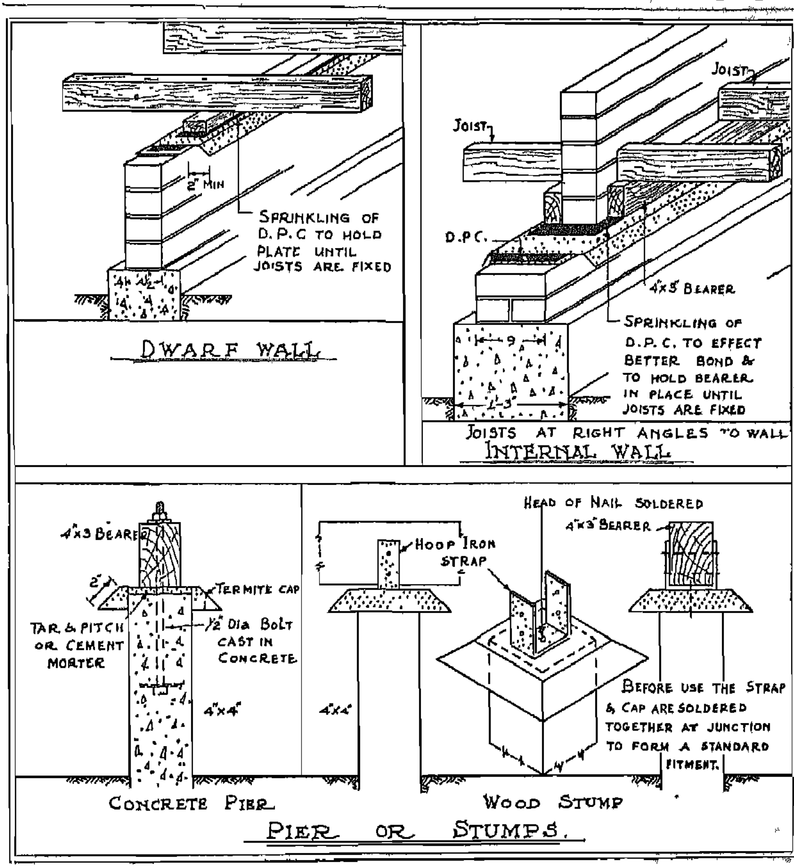

Fig. 202. Anti-termite designs for raised floors and timber buildings; see text.

experimental tests, but neither criterion is infallible. Woods of high lignin-content are very resistant or immune to termite attack and those with lowest lignin-content are most susceptible. In any case the degree of resistance is relative, and the variable, often contradictory, reputation of the same species of timber in different conditions of use is as much due to the prevalence of wood-rotting fungi as to the occurrence of wood-eating termites. From general experience the following species of timbers are considered to be relatively resistant to destruction by termites in India; no species as such is absolutely and permanently immune, and individual trees of the same species often vary considerably from the average. Heartwood or truewood is meant in all cases; the sapwood of all trees is liable to decay and all decayed wood can be destroyed by termites:—

Resistant timbers: *Acacia arabica, Albizzia lebbek, Artocar-*

pus hirsuta, *Bursera serrata*, *Cedrus deodara*, *Chloroxylon swietenia*, *Dalbergia latifolia*, *Dalbergia sissoo*, *Hardwickia pinnata*, *Hopea odorata*, *Hopea parviflora*, *Lagerstroemia flos-reginae*, *Lagerstroemia lanceolata*, *Melia indica*, *Mesua ferrea*, *Ougeinia dalbergioides*, *Populus euphratica*, *Schleichera trijuga*, *Shorea robusta*, *Shorea talura*, *Stereospermum suaveolens*, *Tectona grandis*, *Terminalia manii*, *Terminalia paniculata*, *Terminalia tomentosa*, *Xylia dolabriformis*, *Xylia xylocarpa*.

The reputation of the timbers listed above is in most cases based on service in buildings or under shelter and not in contact with the ground.

Durability tests: The usual method of testing a timber is to bury a piece of the heartwood partly in the ground and to leave it for several years. By this procedure it is subjected to the decaying action of weather and fungi as well as of termites, but of only those ground-dwelling termites that happen to be native in the locality; such tests do not ascertain its reaction to other species or to the characteristic house-termites (p. 538). Tests of this kind carried out in India, Burma, Malaya and Ceylon show that a durable timber varies much in its resistance to termite and fungus attack in different localities. Some species have an excellent general reputation for durability under average conditions of service, nevertheless they may fail within 2 or 3 years under abnormal conditions; on the other hand, some definitely perishable species may stand up unexpectedly for 20 years or more.

Dehra Dun: Over 200 species of Indian timbers have been or are being given durability tests in the 'graveyard' at the Forest Research Institute, Dehra Dun. Here the most abundant species of termites are *Cyclotermes bangalorensis*, *C. obesus* and *Heterotermes indicola*. Trotter, 1940, pp. 30-32, lists 78 timbers classified according to their order of durability when exposed in test-pieces 2′ × 2″ × 2″ for over 5 years; and earlier data were published in 1934. The heartwood of some of the test pieces was SOUND after 5 years, the rest were slightly to badly attacked in:— *Artocarpus hirsuta*, *Bursera serrata*, *Dalbergia latifolia*, *Dalbergia oliveri*, *Dalbergia sissoo*, *Eugenia jambolana*, *Hardwickia binata*, *Heterophragma adenophyllum*, *Hopea parviflora*, *Melanorrhoea usitata*, *Pentacme suavis*, *Pterocarpus dalbergioides*, *Shorea obtusa*, *Shorea robusta*, *Shorea talura*, *Soymida febrifuga*, *Terminalia manii*, *Terminalia paniculata*.

Ceylon: The commonest soil-burrowing termites are *Termes horni*, *Hypotermes obscuriceps*, *Cyclotermes redemanni* and *Coptotermes ceylonicus*. The following species are considered to be "immune":—*Artocarpus integrifolia*, *Azadirachta indica*, *Bassia latifolia*, *Borassus flabellifer*, *Chloroxylon swietenia*, *Diospyrus ebenum*, *Hopea odorata*, *Mesua ferrea*, *Mimusops hexandra*, *Pericopsis mooniana*, *Tectona grandis*, *Thespesia populnea*, *Vitex altissima*, *Xylia dolabriformis*.

Malaya: Several species of termites are present in the experimental areas; among those identified are *Macrotermes gilvus* and *Schedorhinotermes malaccensis*. Dry wood termites are considered to present a more serious potential problem than do subterranean termites (Desch). The heartwood of the following species may remain in the ground for 5 years without attack:—*Balanocarpus heimii*, *Hopea micrantha*, *Madhuca utilis*, *Shorea laevis*, *Shorea maxwelliana*.

Use of treated timber.

Pressure and open tank treatments: The most satisfactory method of rendering timbers termite-proof is impregnation under pressure with coaltar creosote and is essential when permanent immunity is desired. The open tank process can be relied on to give protection for 10-15 years under favourable conditions. Full details regarding both processes and the most suitable preservatives to use can be obtained from the section of Wood Preservation, at the Forest Research Institute, Dehra Dun. See also Popham, 1931.

Brush treatment: For temporary protection 3 coats of hot coaltar creosote can be brushed on the surface of the wood, each coat being allowed to dry before the application of the next. Crude oil, fuel oil or Diesel oil are sometimes used as cheaper diluents for creosote, and various well-known proprietary brands of preservative oils are used when expense is not the main consideration. For interior woodwork which cannot be oiled, water-soluble or colourless antiseptics such as zinc chloride, sodium fluoride, certain arsenicals, chlorinated naphthalenes, etc., are prescribed for brush or surface treatment. These compounds are to some extent fungicides and in that capacity delay or prevent attack by termites, p. 529.

Brush treatment is fairly effective for interior and sheltered work if repeated at regular intervals, and if the wood is thoroughly dry and sound before the first application, and if the periodical treatments reach every part of the wood surface. Practical difficulties arise in buildings because of the inaccessibility of those parts of the woodwork joined to other wood-members, or inserted in or attached to the walling; and such parts are the most vulnerable to termite attack. These defects must be recognised as characteristic of brush treatment (Trotter, 1938).

Information on the design and construction of treated wooden floors, walls, roofs, etc., will be found in:— *Treated Wood for Flooring*, 1936, Wood is good, No. 22, pp. 18, Timber Development Section, Forest Research Institute; *Treated Wood for Walls and Ceilings*, 1936, idem, No. 23, pp. 11; *Treated Wood for Roof Trusses*, 1936, idem, No. 21, pp. 8, figs. 2; *Cheaper and better Gable Roofing with Wood Shingles*, 1936, idem, No. 6, pp. 17, *How to build wooden Earthquake and Storm-proof Houses*, 1936, idem, No. 11, pp. 8, figs. 9; *Wood versus Steel for framed Buildings*, 1936, idem, No. 18, pp. 9.

1 b, REMEDIAL MEASURES

Evidence of attack: The infestation of buildings by termites may be recognised by the presence of (a) earth-covered runways in the cracks and joints and over the impenetrable surface of floors and walls, (b) earthern tubes projecting from various positions, (c) the shed wings of flying termites that have emerged within rooms, (d) the dry powdery pellets of excrement thrown out of cracks by dry wood termites, and (e) hollowed out woodwork with soldiers and workers *in situ*.

Temporary remedies: An earth-floor which is protected by a roof can be freed from termites by treatment with zinc chloride. The floor should be well watered so as to make the earth damp to a depth of 3 or 4 inches. After the water has been absorbed a second watering with a 20 percent solution of zinc chloride is applied so that an average concentration of 4 oz. zinc chloride per sq. ft. of surface with an average penetration of 1 inch depth is obtained. This remedy is too expensive to adopt except where the building is used for storing valuable susceptible materials.

Repair settlement or contraction-joints in a sectional concrete floor with pure cement or coaltar pitch according to the width of the crack and its accessibility. Widen the crack to a triangular depression and clean out all dust and brittle edges, using a brush, and then fill; coaltar pitch is better than asphaltic compounds or cement in places where there is a wide range of variation in temperature and wetness.

Open up cracks and holes in walls, etc., by tracing back the runways and tunnels of termites at work as much as is needed to remove broken and disintegrated mortar, concrete, etc., or rotten wood, and clean thoroughly of all dust and fragments. If the cavity appears to be of limited extent soak or swab it with creosote, earth oil or tar. If the cavity is connected with further inaccessible tunnels or is extensive and irregular treat it with a fine dry poisonous dust, either dropped in with a spoon or blown in with a dust gun. Use Paris green, white arsenic or sodium fluosilicate; the arsenicals are quicker acting, but if they cannot be used without danger to the operator, sodium fluosilicate is a satisfactory if slower acting alternative. Fill up treated cavities finally with cement. Dust treatment is more effective and more extensive in its action than oiling, as the dust is carried by the termites themselves on their bodies and distributed throughout the colony.

Badly damaged woodwork that can be taken out should be replaced by fresh material properly treated with preservatives. Extensive renewal of woodwork can scarcely be considered a temporary remedy. If damage occurs in damp places due to the leakage or splashing of water, the drainage should be improved, leaks repaired and ventilation provided. Termites in furniture, boxes, etc., can be killed by putting the articles out in the sun for some hours; ants help in cleaning things up.

So long as the chance of reinfestation of the superstructure exists by (a) the arrival of fresh lots of worker termites from underground, or (b) the formation of new colonies by fresh swarms of winged adults the remedy is only temporary. Hence, frequent inspection in all parts of the building is needed throughout the season of activity and particularly during rainy periods.

Permanent remedies: Permanent protection in termite damaged buildings is obtainable by applying the same principles as have been outlined under Preventive Measures, p. 933.

Against subterranean termites: All untreated woodwork must be completely disconnected or isolated from the ground on which the building stands. Infested timbers need not be removed or replaced unless seriously weakened structurally. If termites already present in such timber are cut off from the source of moisture in the ground or due to leakages in the superstructure and roof, they will soon perish. The methods by which timber is isolated from the ground, pp. 938-940, necessarily involve structural alterations to old improperly constructed buildings. Remove timber in contact with the ground or shorten and replace it by a layer or pier of concrete properly isolating the earth from the timber above. Wooden blocks or plugs inserted in walls for the support of shelves, panelling, skirting boards, picture rails, hooks, etc. should be taken out and replaced by completely impregnated blocks in a well-cemented cavity. The ends of beams entering masonry or concrete should not be sealed but should be provided with boxes affording an air-space at the end of the member of not less than 1 inch on all sides. Walling in which inferior mortar has been used, or which has a core of earth or rubble, should be faced on all sides with Portland cement. Metal termite-shields fitted to such walls would be ineffective unless accompanied by a layer of cement-plastering and capping to complete the barrier.

Against non-subterranean termites: Where the danger of infestation by flying termites is persistant, all exposed woodwork should be periodically treated with antiseptics or replaced by impregnated wood. Doors and windows should be provided with wire-gauze screens, which should be kept closed during the swarming season of the local termites.

2. PROTECTION OF STORED OR CONVERTED TIMBER

Timber yards and mills: Keep the ground of the depot or yard as dry as possible by adequate drainage, and clean of material attracting termites by avoiding the accumulation of odds and ends of lumber, sawdust and rubbish generally.

Stored timber which is not housed in sheds with paved, or brick, or concrete flooring should be stacked on supports of concrete, or brickwork, or stone, or iron rails, or a creosoted wooden framework; these supports should be periodically inspected for termite runways. Where the danger is great (depending on the local species of termite) the foundation pillars or walls should be capped with termite-proof metal shields [figs. 201, 202]. In properly built stacks with adequate air-circulation there is little danger of nests being established by flying termites. For correct methods of stacking timber see Kapur, 1934. When permanent piers, or grillage, or stacking framework are not erected, soak the ground with waste engine oil, sludge or crude oil.

Wooden structures, and timber in service whether used in the round or dimensioned; e.g., fence-posts, telephone and transmisson

poles, wooden tent-pins, bridges, railway sleepers, etc. when used in contact with the ground can only be protected by **impregnation** with creosote and oils, or with water-soluble antiseptics. Surface-treatment by painting with a brush or swabbing with a cloth is not sufficient. It is effective for only a very short time and cannot be repeated on imbedded parts of the structure.

Fence posts and fencing: The posts should be green and with the bark on; freshly felled posts give the best results but the time that may elapse between felling and treatment depends on the season of the year. A small portion of the bark is peeled off at the butt end and a piece of an old motor inner tube about 2 feet long is forced for a few inches over the peeled end and tied in place. The post is supported so that the preservative can be poured into the rubber tube. The preservative replaces the sap which flows out at the opposite end. When the preservative begins to appear at the other end in more or less the same concentration as in the motor tube reservoir and its presence can be detected throughout the treatable cross-section of the post at the lower end, the treatment is complete. Further details are given in Trotter, 1938. Possible solutions are copper sulphate, zinc chloride or sodium arsenite 10 percent, or Ascu 6 percent.

When an increased life is required not exceeding 2 to 4 times that of untreated wood, soak the material for several hours in preservatives in an open tank followed by a few days' air-drying. When an annual consumption of several hundred posts is anticipated it is advisable to install a small pressure plant. Information on the design and operation of a portable cylinder pressure plant can be obtained from the Utilisation Officer, Forest Research Institute, Dehra Dun.

Charring the butt ends of fence posts is a cheap way of obtaining protection for a limited period. The wood should be quite dry and the charring should be done slowly preferably with a blow lamp. It is a common form of protection in hill districts where the liability to attack by fungi and termites is not so serious as in hot and humid regions (Hakimuddin, 1938).

Poles and posts: Complete impregnation with a preservative by pressure is the ideal treatment for wooden poles and posts mounted with the butt end in the ground, e.g., as house posts, telephone, telegraph and transmission poles. A pole which must have about 1/6th of its length permanently buried in the ground requires a more thorough preservative treatment than does a railway sleeper which is normally laid on well drained ballast, or than do beams and joists exposed in buildings. Coaltar creosote occupies an unchallengeable position in Europe and America as the best preservative for the treatment of wooden poles. It has definitely relegated all water-soluble preservatives to a position of minor importance. Poles in India should be treated with a good type of high boiling creosote, and a minimum absorption of 10 lbs.

of creosote plus 5 lbs. of fuel oil per cuft. should be prescribed. An average life of over 20 years and a possible maximum of 50 to 60 years may be expected with such high absorption. There should be no great engineering difficulty involved in the designing and manufacturing in India of small-scale creosoting pressure plants with treating equipment suitable for the treatment of poles on any scale desired (Stewart, 1940).

The equipment and process for open tank treatment are described by Popham, 1931, A high boiling creosote should give good results with timbers that have durable heartwood and sapwood that is easily penetrable under open tank conditions.

Brushing and charring: A timber of which the heartwood is highly resistant to decay and to termites must be used; the sapwood at the butt end is removed and the preservative is brushed on the exposed heartwood surface. At the time of erection of the pole the pit to receive it is well soaked and puddled with crude oil or creosote, and soil saturated with oil is used to fill the pit. A better absorption of oil is obtained if the butt end of the pole is charred before oiling so as to form a compact sterile shell of carbonised or partly carbonised wood. Charring is not always effective unless carried out on seasoned poles, as the subsequent splitting exposes untreated wood. In the case of house posts it is economical to bed them in concrete foundations, provided they are not in any way sealed and have space for shrinkage and swelling. The concrete sole gives a firm base and the surrounding concrete resists any cantilever action. This can be combined with the oiled termite gutter advocated on page 939. Brush treatment with water-soluble antiseptics cannot be relied upon to give protection against termites, or borers under outdoor conditions.

3, PROTECTION OF LIVING TREES
PREVENTIVE MEASURES

Seedbeds, nurseries: When making a nursery for trees in cleared forest land, clean the site of all woody surface debris, logs, stumps etc., and destroy termite nests as recommended for sites for buildings (p. 933). Such a preliminary cleanup is the most effective preventive measure; it helps also in cleaning up other soil pests, such as cockchafer grubs and root- or weed-feeding larvae. The nursery can be partially isolated from later invasion through tunnels in the soil by digging a deep trench round its perimeter. Wooden boards used for the edges of seed-beds, wooden posts for supporting shade-matting or thatch, wooden labels for the beds and such like should be creosoted to avoid supplying food which will cause a concentration of termites near the plants. Litter, humus, or manure brought in from outside should be inspected for the presence of termites and if infested should be sterilised by spreading in the sun or raking over and

compacting. Some oil cakes such as castor, karanj, mohwa and neem oil cakes, which have manurial value, also have a limited deterrent effect on termites.

Seeds: Nothing can be done to prevent termites attacking the seeds fallen from trees in the forest; on the other hand use can be made of termites to prepare seeds for germination. In some divisions teak seeds are regularly exposed so that the hard outer testa is eaten away.

Transplants: Much of the subsequent termite-attack on transplants is due to injury to the roots at the time of lifting or by bad root- and top-pruning which causes breaks, splits or bruises.

Desiccation of rootlets and of tissues near cut or broken places is another contributory cause. Injured roots die back during the dry season and also during periods of water-logging. Termites first attacking the dead roots can continue to work on the living tissues when the resistance of the plant is lowered. Prompt and careful transplanting is the cure. Under special circumstances stumps, or root-pruned transplants, may be dipped in poison just before putting into the planting hole. If bamboo or switch baskets are used for transplants they should be poisoned, otherwise they will attract termites. The poisons are 5 percent lead arsenate in water, or 2 percent Paris green plus 4 percent lime in water. The treatment will give protection until root-formation begins. A proceedure suitable for the kind of cooly employed needs to be worked out to avoid danger to the cooly.

Patch sowings: Seeds dibbled in small numbers or broadcast on small patches are liable to attack if the soil contains an abundance of leaf and woody litter. Hence sowings on ash-beds are more satisfactory. Stakes that are used to mark patches of sown seeds should be dipped in creosote or earth oil.

REMEDIAL MEASURES

Nurseries, etc: When young plants are observed to be dying off in seedbeds and in nurseries, the lines should be systematically examined and the upper layers of soil turned back and searched for termites. The dying may be due to cockchafer grubs, cutworms, crickets, etc., or to drought or to damping off. If termites are responsible the best treatment in the dry season is watering the lines with weak crude oil or fish oil emulsion, p. 858. As the weakness of the plants is often due to deficiency of soil-moisture watering gives the needed stimulus and the oil emulsion keeps away the termites. Ordinary watering or irrigation often improves conditions for termite-activity at the soil-surface and increases the damage. If the nursery is irrigated the oil emulsion may be applied simply by suspending a cloth or sacking bag of undiluted emulsion in the main water-channel. The dosage should be arranged to give about 5 seers to the acre.

Watering with nicotine water is also a useful remedy (see

under transplants).

In the wet season and when the soil is permanently moist dust Paris green or white arsenic (arsenious oxide), mixed with several times its bulk of dry dust or sand or ashes for even distribution, along the lines of plants after turning back the top layers of the soil. Para or ortho-dichlorobenzene (crystals or liquid) can be used as a slow acting fumigant along the lines. The most suitable termiticide to use and the strength at which it is effective depend largely on the age and species of the plant (some trees are susceptible to soil insecticides) and on the kind of soil and the season of year.

In the absence of a properly tested insecticidal measure or delay in obtaining insecticides, it is useful to dig over the soil of the beds repeatedly at short intervals, which will disturb the termites and drive them elsewhere, e.g., into trenches or waste ground which have been baited with sawdust or dry grass that must later be burnt. Permanent baits of sawdust or chips and small pieces of softwoods, poisoned with Paris green (100 parts wood to 1 part Paris green) or saturated with a 10 percent solution of sodium arsenite can in future be kept in stock.

An interesting method is to use red ants or black ants (Formicidae). Find an ants-nest in the jungle near the nursery and dig it up and carry the earth mixed with ants in a kerosene tin or box or sack to the nursery and spread it over the seed-beds; the ants will find the termites and kill them. At the Lac Research Institute near Ranchi, *Solenopsis geminata rufa* has been used successfully for this purpose; many other kinds of ants will do the same.

Transplants & young saplings: In irrigated plantations crude oil emulsion can be used to protect transplanted stumps and cuttings by suspending bags of the concentrated emulsion in the irrigated channels, or by arranging automatic drip containers. If canal water is not available hand-watering must be resorted to.

Hookah water or extract of tobacco leaves is suitable for watering by hand and is particularly effective for the more delicate trees such as *Eucalyptus*. Steep one pound of country tobacco leaves in a large pot full of water, leaving it overnight and squeezing the leaves dry next day; this quantity is sufficient for 15 to 20 plants. Watering should be done at two seasons, before the rains begin, and in the hot period after the cessation of the rains. At the end of the 2nd year the plants should be strong enough to withstand further termite-attack.

Arsenate of soda made from 1 lb white arsenic (arsenious oxide) and 2 lbs commercial washing soda in 1 gallon of water may be used diluted with 10 times as much water; or arsenate of lead 1 lb in 16 gallons of water may be used for watering individual plants.

Poles and older trees

Injury to the wood: Against species like *Kalotermes* which

excavate tunnels and nest-cavities in the heartwood of living trees, p. 538, Paris green is an effective poison. A hole is drilled through into the cavity with a gimlet or brace and bit and the powder is blown into the hole by means of a rubber bulb as used for an atomiser or enema syringe and the hole closed with tree wax or asphalt or tar and sand. The bored hole should allow the tapering nozzle of the syringe to fit closely so as to avoid a blow-back of the powder. Tea bushes in Ceylon and fruit trees in Australia are successfully treated by this method.

For termite attack in plantations of the sapling and older stages no practical remedy is available. In the case of an exceptionally valuable crop on a par with tea, rubber and coconut, or in the case of isolated trees, roadside and garden avenues, etc., direct protective measures are possible. Trees that have been neglected until rotten areas and hollows have formed, should be cleaned out or pruned down to the sound wood and a strong solution of arsenate of lead (see above) poured or injected into accessible cracks and cavities, or in specially drilled augur holes. Later the wounds should be tarred.

Injury to the bark: Against termites that work on the bark externally under cover of tunnels or sheets of earth protective bands can be applied near the base of the tree. The work of such termites is rarely injurious to healthy trees, though it is frequently erroneously suspected of killing trees; where branch snags or wounds or fire-injuries are present, termites may obtain access to the heartwood and certainly prevent wounds from healing. For trees in avenues or in the compounds of resthouses, etc., measures may be desirable.

Gambir mixture: "Dissolve 3 pints of gambir in 12 of dammer oil over a slow fire; then stir 1 part of lime, sprinkling it over the top to prevent its coagulating and settling in a mass at the bottom; it must be well and quickly stirred. It should be then taken out of the caldron and well ground down like paint on a muller till it is smooth and afterwards returned to the pot and heated. A little oil should be added to make it tractable and the composition can then be laid over the material" (Cleghorn, 1861). Gambir or Terra japonica is an extract from the leaves of the climbing shrub, *Uncaria gambir* Roxb., strained, cooled, hardened and cut into cakes. Dammar oil is obtained from *Canarium strictum* Roxb., and also from species of *Hopea*, *Shorea* and *Balanocarpus*. Katha, the dried aqueous extract of wood of *Acacia catechu* could be substituted for gambir.

Gondal fluid: 1 part dikamali gum (from *Gardenia gummifera* or *G. lucida*), 2 parts assafoetida, 2 parts bazaar aloes, 2 parts castor oil cake. Grind up finely and mix thoroughly. Keep in water for about a fortnight and when decomposed into a thick mass add water till the mixture is of the consistency of paint. Apply in a continuous band round the trunk a short distance above ground. If necessary clean and scrape the bark with a

wire brush. One application should last for at least 8 months and throughout one monsoon.

Bark cracks: An abnormal type of injury sometimes occurs in rapidly growing saplings and coppice-shoots of species of trees that expand their bark by longitudinal cracks. Unusually rapid growth may cause the bark to split down to the sapwood and these fissures are invaded by termites which prevent the wounds from healing and gradually extend the dead areas until in extreme cases the stems are girdled and killed. The remedy is silvicultural, i.e., proper regulation of overhead shade and thinnings to prevent excessive growth (see p. 537).

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ARCTIIDAE, p. 559.

AN outbreak in a forest of **Amsacta, Creatonotus** or **Diacrisia** may be due to (*a*) external causes, e.g., the migration of caterpillars from agricultural crops near the boundary of the forest or from crops in taungyas and kumris on regeneration areas, or (b) internal causes affecting the survival of the hibernating and aestivating generations because of changes in fire-protection and soil-protection.

Moths: Against *Amsacta albistriga* in agricultural land, collection of moths by hand is the usual practice. Pupation takes place deep in the soil beyond the reach of the plough. The moths begin to emerge at the onset of the monsoon with the first showers and continue to emerge in instalments a day or two after each heavy fall of rain throughout the early monsoon season; they are sluggish, conspicuous and easily caught on low vegetation by children or women. As each female moth lays 1,000-1,500 eggs, regular destruction of this instar at this season of year is justified. In an organised campaign hand-picked moths are paid for at one pice to one anna per hundred; the catch is squeezed and dropped into a vessel of kerosened water for purposes of counting and payment.

Egg-masses: Moth-catching is supplemented by destruction of egg-masses which are conspicuous yellow patches on leaves and are readily detected. This operation overlaps collection of moths in the latter part of the emergence-period.

1930, *Dept. Agr. Madras*, Leaflet No. 23, The red hairy caterpillar pest, Amsacta albistriga (Also in Kanarese, Tamil and Telegu) — 1915-1919, *Mysore Agric. Calendar*, Control of kumbhhulas — 1923-1934, *Ann. Rep. Mysore Agric. Dept.*, and *Rep. Progress Agric.*, *Mysore.*

Silvicultural: An outbreak of Arctiidae in forest land which is autochthonous, i.e., generated on the spot and not due to invasion from agricultural land, may be caused by (i) changes in policy and efficiency of fire-protection, by departmental burning or by accidental fires; destruction of the soil-litter by burning may upset the balance in two ways, either by killing the aestivating or hibernating stages of the arctiid defoliators, or by killing the alternative hosts of their parasites and diseases—the replacement of a humid soil-cover by dry conditions is particularly inimical to

bacterial diseases of caterpillars Or an outbreak may be caused by (ii) changes in the conditions for pupation in the soil · working the soil in preparation for regeneration or in agri-horticultural operations, and weeding or scraping the soil in subsequent tending of the young tree crop, may provide the pest with better facilities for pupation at a safe depth. Control measures must therefore be based on a modification of the silvicultural practice that favours the pest and must be devised to suit the particular factors of the locality and the period.

Remedial Protection against migrating swarms of hairy caterpillars is possible by direct measures if the trouble is detected in time. Handpicking or spraying or dusting the caterpillars is a tedious and costly remedy that is not justified. Steep sided trenches, a foot deep and as broad, can be used to isolate areas that are exposed to invasion by swarms, the caterpillars fall into the trench and tend to proceed along its length rather than climb out, and so concentrated may be destroyed more easily.

BLASTOBASIDAE, p. 562

Cladobrostis melitricha, p 564. In susceptible regions adopt closer espacement in early youth so as to avoid production of weak whippy shoots on the lower part of the stem. On the regeneration area cut back free-branching, isolated, advance growth of shisham from which the borer may spread and attack leading shoots of transplants.

Holcocera pulverea, p. 564, see later, *Laccifer lacca*, Coccidae.

COSMOPTERYGIDAE, p 569

Eumenodera tetrachorda, p. 571, is scarcely controllable except by spraying intended for *Lecanium longulum*, Coccidae.

COSSIDAE, p. 572

Xyleutes ceramica, The Beehole Borer of Teak, p. 573

Atkinson D J, 1936, *Ind For, Rec*, Ent, II, No 1, A survey of the damage to teak timber by the beehole borer

Beeson, 1921, *tit. cit*, VIII, III, The beehole borer of teak.

DIRECT measures for the elimination of this pest are not practical. Partial reduction of its potential damage can be obtained by silvicultural measures and there are prospects of auxilliary biological measures. These are discussed under the heads of Plantations, and Natural Forests.

PLANTATIONS

Location: The natural incidence of beehole in teak plantations in Burma has been surveyed (Atkinson, 1936) and three main zones have been recognised and delimited —light, moderate and heavy. The variation in the incidence is correlated with meteorological conditions, especially the mean annual rainfall. Between the isohyets of 70″ and 110″ the conditions governing

the incidence of beehole are at or approaching their maximum; teak grown under these conditions will inevitably be severely damaged. Artificial regeneration of teak should be discontinued within such areas—the heavy and upper moderate zones. The isohyet of 60″ constitutes the dividing line between light damage and moderate to severe damage. Below 55″ rainfall and at 150″ and above, damage by beehole is likely to be slight to negligible. In Burma there are 12 forest divisions within the light and lower moderate zones in which artificial regeneration should be permissible without high beehole hazard (see Atkinson, 1936, p. 72, and map). Considerable variation in beehole-incidence can take place within very narrow limits; therefore, a pronouncement that a given locality is or is not suitable for artificial regeneration must be based on evidence obtained by the analysis of the past histories of an adequate number of sample trees.

Silvicultural measures: The frequency and intensity of thinnings in plantations affect the population-density of the borer and the beehole-incidence per tree. If trees marked in thinnings are felled during the cold weather the borers living in them are more likely to die before maturity than if the trees are felled just before the moth-emergence period. As the number of moths per acre is normally small, the destruction of even one female is important. The more frequent the thinnings the more uniform the reduction of the borer-population. A tree should not be selected for thinning because it displays a visible beehole scar; only a very small fraction of beeholes in the tree can be detected by the marking officer. In an even-aged crop relatively more borers per tree will be destroyed in the middle girth-classes and dominated trees than in the suppressed trees; suppressed trees do not act as trap trees.

Thinning should be regulated so that the timber-increment, which normally outstrips the borer-increment, is raised to the maximum possible for the stand as a whole and particularly in those trees which will form the final yield. Whatever the local incidence of beehole, the faster the timber can be grown the less will be the material effect of any degree of beeholing and the greater will be the volume of (more or less) beehole-free timber. This effect operates very decidedly to the advantage of the plantation as only under exceptional circumstances can naturally grown timber compete in rate of growth with the plantation product. For existing plantations lying within the heavy zone it must be decided whether further maintenance-operations are justified or the plantations should be abandoned. In the better quality stands a possible method of minimising the eventual degrade through beehole lies in the encouragement of the fastest possible growth in the dominants for the remainder of the rotation by means of heavy and repeated thinnings. Where the crop is unlikely to answer to such treatment, e.g., Class III plantations,

nothing can be done, and any further money spent on their future maintenance will be wasted. They should be written off; apart from beehole it is improbable that any Class III plantation can continue to be a financially sound proposition beyond the age of about 45.

Biological measures: The natural factors controlling *Xyleutes ceramica* in Burma are very effective in the biological sense: the species is not abundant in individuals: it is a relatively uncommon insect. This is due primarily to high mortality in the early larval stages caused by dispersal, meteorological conditions, predators such as Formicidae and woodpeckers and in the slightly older larval stage, caused by parasites.

Parasites: The possibility of improving control by the parasite *Nemeritis tectonae*, p. 509, is the subject of research; the objectives are (i) artificial multiplication of parasites and release of adults in plantations, and (ii) natural multiplication of parasites by increasing the abundance of the alternate host, *Indarbela quadrinotata*, p. 620, which could be achieved by retention or encouragement of those species of trees that support this bark-eating caterpillar.

Predators: Conditions which maintain a resident population of woodpeckers are desirable. As several species of woodpeckers which feed on *X. ceramica* larvae feed primarily on ants, conditions which favour a permanent population of ants, themselves enemies of the borer, are desirable. See sections on Birds, p. 824, p. 850.

Alternative food-plants: The alternative food-plants of *X. ceramica*, p. 573, although of slight importance when sporadic, should not be permitted to occur in large concentrations.

NATURAL FORESTS

Silvicultural measures: The very great importance of fast growth of teak in natural forest cannot be exaggerated. Improvement fellings should be regulated so *that the timber-increment* does not fall behind the *borer-increment* for the locality. If the current annual increment of a tree falls below the growth curve designed for the rotation, not only is the volume-production uneconomic but the timber previously formed becomes relatively more severely beeholed with the lapse of time. Natural teak in zones of light or lower moderate biological incidence, which puts on negligible increment or stagnates, will yield severely beeholed timber.

Mixtures: Dilution of teak stands with any other species has no appreciable effect on the incidence of the borer until the proportion of teak becomes so low that it must be classed as a natural mixed forest; in a mixed forest the biological incidence is less than in a pure plantation in the same locality; but the difference in incidence is not so great as is popularly supposed

for crops of the same age and same rate of growth. On the other hand, dilution of teak stands with the alternative food-plants of *X. ceramica* is equivalent to and as harmful as increasing the proportion of teak.

Xyleutes persona, p. 580: Because its incidence per tree is very high in serious outbreaks, it is essential to cut out and destroy heavily infested trees. For valuable shade or ornamental *Cassias* the remedy is direct treatment of the tunnels (as for *Zeuzera* below) with pruning, tarring and repair of wounds, and manuring.

Zeuzera coffeae, The Red Borer, p. 581: The presence of an active borer is indicated by red or yellow pellets of ejected frass on the ground below or by dry foliage. Locate the ejection-hole and probe with a slender, flexible, green twig from which the bark has been stripped or with a grass stem or splinter of bamboo; wire is not recommended and there is no need to enlarge the hole or cut the wood elsewhere. Fill the main hole and any additional ejection-holes with tar; then hold the twig between the thumb and forefinger at about ½ an inch from its end and feel for the downward right angle turn in the tunnel; if the twig is sufficiently slender and flexible it can easily be pushed down the whole length of the vertical tunnel and will pierce the larva. Leave the twig in situ as an indication of treatment and sweep away the frass from the base of a treated plant. Smear more tar in the hole to keep out Formicidae, etc. Young plants of *Casuarina*, *Santalum*, *Tectona*, etc., treated in this manner recover and readily heal the wound.

The ability of the Red Borer to breed in a large number of alternative food-plants makes it difficult to prevent attack in nurseries and young plantations adjoining natural mixed forest and the direct remedy is necessary. Patrol the area frequently to locate attacked plants. Remove and burn those killed; prune off dead branches to the base of the tunnel. Species which coppice well can be saved by cutting back in the early stages of the attack. If the tunnel extends down into the main stem beyond the level of practicable pruning, kill the borer with a probe. In pure plantations (e.g., *Casuarina equisetifolia*) in which the older stands are the main breeding-grounds and there are no subsidiary breeding-places in the undergrowth or adjacent jungle, frequent inspection of the young compartments is needed in order to save attacked plants. It is not practical to prune or collect broken branches in older stands. Dense stocking is the cure, p. 844.

Zeuzera multistrigata and other species, p. 583, are controllable in small plants by similar methods; a practical method of dealing with attacks on the leading shoots of tall poles and the trunks of larger trees has yet to be devised.

EUCOSMIDAE, p. 585

Argyroploce, p. 585, and **Enarmonia**, p. 587, **Eucosma**, p.

588 and similar leaf-rollers and borers. Until the ecology of these species has been worked out they are not controllable except by direct remedies such as spraying with stomach-poisons plus oil emulsion. Having short life-cycles and a specialised method of feeding, their abundance is regulated by the vegetative activity of the food-plant and increases abnormally when that is deranged.

Pammene theristis, p. 589. Extensive study of the complex ecology of this species is needed.

EUPTEROTIDAE, p. 590

Eupterote geminata, E. mollifera, E. undata, pp. 590–592.

The full-grown caterpillars assemble in the autumn and cold season in close masses in sheltered places on the trunks of large trees, in hollows, under logs, rubbish-heaps, etc., where they are easily collected and destroyed. If overlooked they pupate in the mixture of loose soil and excrement near such places of assembly. The pupal period lasts for several months (pp. 591, 592) which gives plenty of time for a methodical and complete search for pupating places. The large unmistakeable pupae should be collected and destroyed.

1939, *Dept. Agr. Mysore.*, Circ. No. 65. The cardamom hairy caterpillar and its control in Mysore State.

GELECHIIDAE, p. 592

Dichomeris eridantis, p. 593: The silvicultural measures advised for *Plecoptera reflexa* should on the whole be effective in maintaining the resistance of *Dalbergia sissoo* against this pest in irrigated plantations in the Punjab; it is however not so dependent as *Plecoptera* on the production of young foliage for its survival. The specific parasites of *D. eridantis* are generally distributed throughout the Punjab plantations. The polyphagous parasites, *Phanerotoma hendecasisella*, p. 484, will increase with the increase in the variety of the undergrowth. Direct measures such as spraying or shaking and banding are not advised.

GEOMETRIDAE, p. 596

Ascotis selenaria, p. 597. Until the parasitism of this species has been studied, the best remedy for local outbreaks on *Melia azedarach* in shisham plantations is collection by hand of the mature caterpillars and pupae of the 1st. generation in April.

Biston suppressaria, p. 597, and similar species, lay eggs in masses in the crevices of rough-barked trees and avoid smooth-barked stems. The larvae are dispersed by crawling or carried by wind on threads of silk or gossamer; the newly hatched larva is very active and travels fast and far by looping. For control in plantations of *Aleurites* (Tung-oil tree) in China the following is advised: To prevent infestation, tung-oil trees should be planted at least 500 ft. from forest trees that are suitable for oviposition.

Empty cocoons of Limacodidae on the bark which are also suitable for oviposition should be destroyed. Rough-barked billets 2 ft. long and 3 ins. in diameter should be hung up as oviposition-traps on every third tung-oil tree. Pupae can be trapped by loosening the soil in strips between the rows of trees before the larvae descend for pupation and they can afterwards be killed by hoeing.

Ectropis deodarae, p. 591

In the better quality deodar forests natural control is most effective and the deodar defoliator does not multiply to pest-numbers except possibly under abnormal weather conditions at very long intervals. Natural control breaks down in forests in the outer ranges of the north-west Himalayas in which grazing, the removal of litter and over-thinning, to satisfy village rights, have degraded the forest-community, p. 840. In places where litter is removed and the ground is disturbed by grazing, the sites suitable for pupation are destroyed. The larvae of *E. deodarae* cannot utilise the compacted soil of cattle-tracks and have to find cracks and recesses in the vertical walls of the 'staircase' and around the bases of trees, where predators (*Calosoma beesoni*, p. 123) meet with greater difficulty in finding them. On undisturbed stony slopes the flat, partly embedded, rocks and flagstones are nearly all used by ants for nests; in grazed areas these stones are constantly displaced and the ant-colonies are destroyed. In grazed and under-stocked areas the normal soil flora disappears and is replaced by plants that are indicators of poor or unsuitable deodar sites; consequently the parasite-association is much reduced and with it an essential control factor is lost. Biological control consists in closure to grazing and restoration of the normal humus-layer and soil-flora. On the dying-off of deodar see pp. 868, 869.

Sticky bands: (p. 860). The object of sticky-banding is to prevent the wingless females, which have pupated and spent the winter in the soil, from climbing up the trunks of deodar trees and laying eggs on the needles. The bands should be put out before the first week in March at elevation of 6,000 feet and lower, and they should be kept fresh and sticky throughout March to prevent the moths from crawling through them. The moths and eggs laid below the bands should be destroyed by crushing, by regular patrolling during the oviposition-period in order to prevent the spread of wind-borne larvae. Sticky-banding is the only remedy that can be used in an epidemic.

Semiothisa fidoniata, p. 600. Lac hosts should be sprayed with tobacco-soap, p. 859 (tobacco 500 oz., soap 90 oz. water 100 galls.) which acts as a contact insecticide and prevents oviposition or feeding by young larvae on sprayed foliage.

HEPIALIDAE, p. 602

SPORADIC attacks by **Phassus** spp. are dealt with by direct measures as for *Zeuzera*, p. 956. A very high incidence of **P. malabaricus** means a superabundance of alternative hosts in the vicinity, e g., a dense undergrowth in *Eucalyptus* plantations in the Nilgiris is the cause of *Phassus* attack on *Eucalyptus* and the cure is to cut it back, since this exotic is entirely free from other insect pests. Heavy attacks on teak plantations in the first 2 years can be reduced by using the host plants of *Phassus* as traps, i.e., leave these plants on the area at the time the plantation site is prepared; coppice them at the time of the 1st weeding in the 1st monsoon; do not cut them in the 2nd monsoon until the time of the last weeding or in the cold weather; eradicate or kill the roots of these plants at the end of the 3rd monsoon.

No remedy is known for high inaccessible *Phassus* attack on poles.

HYBLAEIDAE, p. 606

Control of teak defoliators

DEFOLIATION of teak is due to an association of several species of defoliators of which the chief are *Hyblaea puera*, p. 606, and *Hapalia machaeralis*, p. 680, together with other caterpillars, grasshoppers, cockchafer beetles and weevils [fig. 198]. General preventive measures must therefore act against the association as a whole.

Chemical and mechanical control: Owing to the short life-cycles of the caterpillar-defoliators and the constantly shifting foci of increase, direct measures like spraying cannot be used in natural forest or extensive plantations. It would be necessary to have a regular patrol for the immediate detection of incipient outbreaks, and spraying gangs that could act with the speed of a fire-fighting organisation. Ground-fires should not be used to destroy pupating larvae and fallen leaves (pp. 837, 838). Light traps are not effective. In practice this means that remedial measures cannot be used except in nurseries or to save newly planted regeneration.

Silvicultural control

See pp. 818, 839, (pure crops), 833 (silvicultural system), 836 (clear felling).

Subdivision: Large regeneration areas of pure teak should be subdivided and the parts isolated by land carrying mixed tree forest. When natural forest is being converted to plantation the pre existing vegetation is retained on the isolation-barriers; when mature teak plantations are restocked in the second rotation the teak is harvested and the understorey is preserved; fire should be completely excluded in both cases. Silvicultural considerations

should govern the choice and location of the fractions of a regeneration area that are to be perpetuated as reserves for the animal life desired in biological control. As a general guide it is suggested that *(a)* the maximum size of a block to be burnt and planted with teak need not exceed 40 acres, no part of which need be more than 400 yards away from unburnt forest and the average minimum might be 20 acres. And *(b)* the preserved forest may be in the form of strips, patches and wedges wide enough to ensure their protection from fire, and to give shade and shelter to beneficial animals, and to provide a marginal effect preventing early and profuse production of foliage by the adjoining teak; suitable sites are small streams and drainage lines intersecting the plantation, the banks of large rivers, avenues along wide main roads, "failed" teak areas, etc., and these sites should not be used for depots, houses, camps or sources of bamboos and poles for departmental purposes. They should be improved by thinnings in favour of the desirable species listed below, p. 961. Permanent agricultural land within or near plantation blocks is not an undesirable feature.

By means of these exclusions in the form of mixed forest together with those in the form of roads, rivers, unproductive land, etc., the area actually under teak in a compact plantation working circle is not likely to exceed ¾rs of the whole tract. This quarter bearing no teak provides a dispersal region for swarming moths and increases possible mortality before oviposition, but its chief value is as a sanctuary and source of predators and parasites (p. 836).

Summary: i. Retain strips and patches of pre-existing mixed tree growth on felling-areas, particularly along drainage-lines, streamlets and on sites unsuitable for teak; protect the same from fire.

ii. Improve these sanctuaries by eliminating the alternative food-plants of the pests and encouraging the desirable species, p. 961.

iii. Retain a strip of riparian flora along river banks and introduce evergreens along the margins of open spaces to prevent marginal teak from producing low branches and bursting into leaf early.

Biological control

Read biotic control pp. 820–827, biological control pp. 845–850, plant categories pp. 848, 849, soil-cover p. 840, mixed crops pp. 841–844. The inter-relationships of the defoliators, parasites, predators and plants in a teak forest are shown diagramatically in fig. 203. (see p. 828, life-communities).

Desirable plant-species, p. 849, i–iii: The following species of plants are desirable in and near teak plantations because they are the food plants of defoliators that are alternative hosts of the parasites of *Hyblaea puera* and *Hapalia machaeralis*. They maintain a reserve force of polyphagous parasites during the period when the teak defoliators are scarce so that it is ready to attack them when they reappear. These species should be encouraged or protected at the expense of all other elements in the natural soil-cover, undergrowth and understorey inside a plantation

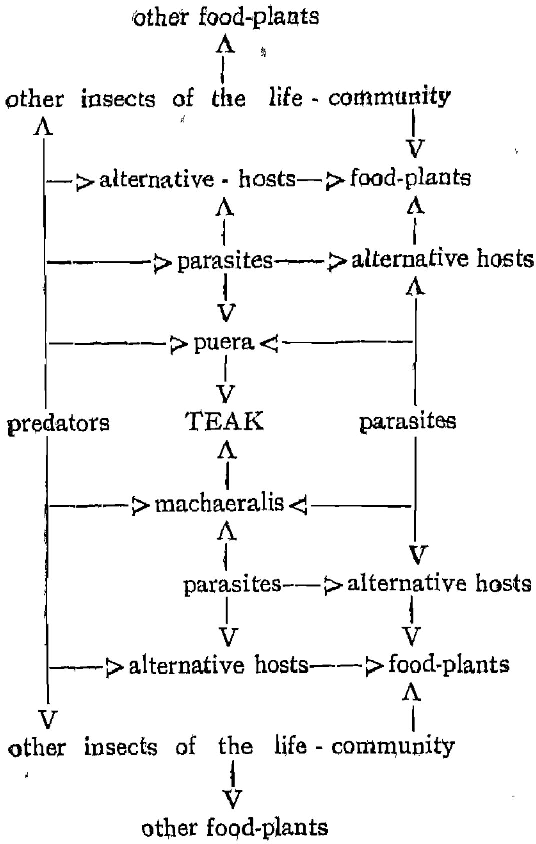

Fig. 203, Food-chains in the teak defoliator-community. (—▷ arrows point in the direction of attack).

and in miscellaneous mixed forest or unplanted exclusions near a plantation. Encouragement should begin on the cleared coupe by exclusion of coppice-shoots, jungle regrowth and seedlings from the weeding and cleaning operations. It should be supplemented by broadcasting or dibbling seeds when the teak stand is old enough to carry an undergrowth. The forester should select and concentrate on those species that are indigenous and suited to the soil and climate. An irregular mixture of species rather than a uniform underwood of one or two species should be the objective. The area should be fire-protected. When the working plan is made this factor should be fully considered; if the objects of management prescribe underplanting with a shade-bearer or secondary timber species or bamboos, the financial advantages of this prescription should be weighed against the loss in increment in the

teak crop which will be the inevitable consequence of increased defoliation.

It should not be concluded that teak trees will be protected in proportion to their nearness to desirable trees; there is not always less crime and fewer traffic accidents near a police-station. Nor should it be expected that protection will be uniform year after year; biological control that is adjusted to an average climate will be less efficient in extremely abnormal weather.

(a) *Achyranthes aspera*, **Anogeissus latifolia**, *Bauhinia racemosa*, *Boehmeria malabarica*, *B. platyphylla*, *Butea frondosa*, *Bursera serrata*, **Careya arborea**, **Cassia fistula**, *Cedrela toona*, *Dalbergia sissoo*, *Derris elliptica*, **Garuga pinnata**, **Grewia asiatica**, *G. disperma*, *G. hainesiana*, *G. humilis*, *G. laevigata*, **G. tiliaefolia**, **G. vestita**, **Helicteres isora**, *Holarrhena antidysenterica*, *Hymenodictyon excelsum*, **Kydia calycina**, *Lagerstroemia flosreginae*, *L. lanceolata*, *L. parviflora*, *Lannea grandis*, *Leea crispa*, *L. sambucina*, *Pterospermum semisagittatum*, **Rhynchosia cyanosperma**, *Ricinus communis*, **Shorea robusta**, *S. talura*, **Sterculia villosa**, *Swietenia macrophylla*, *Terminalia belerica*, *T. paniculata*, **T tomentosa**, *Thespesia lampas*, *Wrightia tinctoria*, **Xylia dolabriformis**, *X. xylocarpa*.

In the above list each of the species supports 6 or more species of parasites of *machaeralis* and *puera*; those in **bold type** support 10 or more species. In the following list (b) are about 60 species which support 3 to 5 parasites each; they represent the next best choice in the absence of species of list (a).

(b) *Abutilon indicum*, *Albizzia procera*, *Alstonia scholaris*, *Bassia latifolia*, *Bauhinia vahlii*, *Boerhaavia diffusa*, *Bombax malabaricum*, *Cassia nodosa*, *C. siamea*, *Celosia cristata*, *Corchorus* sp., *Cryptolepis buchanani*, *Dalbergia latifolia*, *Diospyros montana*, *D. melanoxylon*, *Dipterocarpus tuberculatus*, *Dombeya wallichii*, *Eugenia jambolana*, *E. operculata*, *Eupatorium* spp., *Ficus* spp., *Girardinia heterophylla*, *Gossypium neglectum*, *Grewia microcos*, *Glycosmis pentaphylla*, *Hibiscus* spp., *Hymenodictyon obovatum*, *Leea aequata*, *Mangifera indica*, *Melastoma malabathricum*, *Millettia atropurpurea*, *Morus* spp., *Mucuna prurita*, *Ougeinia dalbergioides*, *Pavetta indica*, *Plectranthus incanus*, *Randia uliginosa*, *Saccopetalum tomentosum*, *Schleichera trijuga*, *Sida cordifolia*, *Solanum* spp., *Sterculia urens*, *Tabernaemontana heyneana*, *Thespesia populnea*, *Urena lobata*.

In the following tabulation 21 species of trees have been selected to illustrate how they contribute to the natural control of *machaeralis* and *puera* through the parasites of their defoliators.

Trees	Defoliators	Parasites			Total
		M	P	M P	
Anogeissus latifolia	5	3	4	4	11
Careya arborea	5	5	6	1	12
Cassia fistula	9	6	5	6	17

Garuga pinnata	3	6	3	1	10
Grewia tiliaefolia and 8 spp.	7	8	4	4	16
Helicteres isora	4	9	3	2	14
Kydia calycina	4	8	2	1	11
Rhynchosia cyanosperma	6	11	4	2	17
Shorea robusta	7	5	5	2	12
Sterculia villosa	4	10	2	4	16
Terminalia tomentosa	10	4	7	2	13
Xylia spp.	4	3	4	3	10

[M = parasite of *H. machaeralis* only, P = of *H. puera* only, M P = of both.]

In this group of trees the most valuable species for association with teak are *Cassia fistula*, the *Grewias*, *Rhynchosia cyanosperma* and *Sterculia villosa*: 33 species of parasites are involved.

The following synopsis shows the distribution of species of teak defoliator parasites and their alternative hosts in the defoliator-complex of *Cassia fistula* alone.

Defoliators, 9 spp.	Parasites, 17 spp.
Cacoecia micaceana 1 M	Cedria paradoxa M.
Catopsilia crocale 3 M P	Compsilura concinnata M P, Elasmus brevicornis M P, Sturmia inconspicuella M P.
Fodina stola 2 P, 1 M P	Eutachina civiloides M P, Sturmia inconspicuoides P, Thrycolyga sp. P.
Glyphodes conclusalis 2 M, 1 M P	Actia hyalinata M P, Apanteles machaeralis M, Dioctes argenteopilosa M.
Hyposidra talaca 2 M P	Compsilura concinnata M P, Sturmia inconspicuella M P.
Nephopteryx rhodobasalis 2 M	Dioctes argenteopilosa M, Phanerotoma hendecasisella M.
Pilocrocis milvinalis 3 M, 2 P, 1 M P	Carcelia kockiana P, Cedria paradoxa M, Dioctes argenteopilosa M, Dioctes gardneri M P, Diglossocera sp. P, Phanerotoma hendecasisella M.
Striglina scitaria 1 M, 3 P	Carceliella octava M, Diglossocera sp. P, Goniozus montanus P, Sturmia inconspicuoides P.
Sylepta balteata 5 M, 2 P, 1 M P	Cadurcia vanderwulpi M, Carcelia kockiana P, Carceliella octava M, Cedria paradoxa M, Dioctes argenteopilosa M, Goniozus montanus P, Phanerotoma hendecasisella M, Sturmia inconspicuella M P.
Total 6 M, 5 P, 6 M P	

Undesirable plant-species, p. 849, iv: The following species of plants are undesirable in and near teak plantations because they are the alternative food-plants of pests of teak. *Callicarpa arborea*, *C. lanata*, *C. macrophylla*, *Clerodendron infortunatum*,

Dolichandrone stipulata, Gmelina arborea, Heterophragma adenophyllum, H. roxburghii, Kigelia pinnata, Lantana aculeata, Millingtonia hortensis, Macaranga roxburghii, Oroxylon indicum, Premna latifolia, Schrebera swietenioides, Stereospermum chelonoides, S. suaveolens, Tecoma undulata, Vitex agnus-castus, V canescens, V. glabrata, V. negundo, V. peduncularis.

Teak defoliators with short life-cycles continue to breed on many of these species of plants during the season when teak is leafless or when its foliage is mature; and consequently, the initial population of pests, at the time teak comes into leaf, is higher than it would be if no alternative food-supply were available. This disadvantage outweighs any benefit that may be supposed to arise from their ability to attract part of the pest-population away from teak. Those species of plants that are food-plants of borers with long life-cycles similarly increase the pest-population. All should be eliminated from plantations and their neighbourhood; they should not be retained in rich teak-bearing forest.

Neutral plant-species, p. 849, v: All species not listed in the preceding pages may be considered neutral from the aspect of biological control except in the very rare circumstances when no desirable species of groups (a) and (b) are available.

Introduction of parasites, etc: In localities where there is a deficiency in the natural enemy complex, the introduction of selected species of known efficiency is beneficial. This is not an operation the forest staff can undertake unaided; the cooperation of the Forest Research Institute in the preliminary entomological survey and in the supply of foreign species of parasites and predators is essential (see pp. 845–848).

INDARBELIDAE, Bark-eating Caterpillars, p. 620

Indarbela quadrinotata, p. 620: In a valuable stand of trees the quickest way of destroying bark-eating caterpillars is to rub off the matted frass from the tunnels in the bark and to dress with tar or bitumen the place where the shelter-tunnel enters the wood. A stiff brush fitted at right angles to the end of a long bamboo is suitable for painting the holes. Other wounds in the bark and snags and stubs should be painted with tar. Collect and burn the frass mats after rubbing off, in case live caterpillars are contained in them. In citrus plantations it is worth while to make sure the caterpillar is killed by probing the shelter-tunnel with a hooked wire or injecting petrol-naphthalene, or calcium cyanide powder and closing the tunnel with clay. In the early larval stage the bark of previous feeding-places may be sprayed with an arsenical, p. 861.

Indarbela attack in abundance is regarded as an indication of unhealthy growing stock and excessive dying-back of branches, p. 872.

LASIOCAMPIDAE, p. 621

Malacosoma indica, p. 622. When epidemics of this oak defoliator begin in hill-stations and in the adjoining municipal and cantonment forests the following remedial measures should be organised.

Eggs: Although the eggs laid in rings on the twigs of tilonj, mehal, willow, etc, remain from May to March unhatched, complete control by pruning, etc, is impracticable.

Caterpillars: Web: The caterpillars hatched in March spin silk webs on the smaller branches in which they congregate, they do not drop when the branches are shaken. Destruction of the webs is feasible by pruning or crushing those within reach and by using a stiff cone-brush or nail claws on a long pole to tear down the higher webs; burning with a torch on a long pole is not recommended The work should be completed before the end of the first week in April. Old webs of the previous year should not be destroyed as they will serve as centres of infection for the spread of the bacterial disease. Lead arsenate (p. 861) is a suitable spray applied when the caterpillars are young and before serious defoliation begins.

Older caterpillars During April the caterpillars while feeding are not concentrated, but are generally dispersed in the foliage and fall readily if branches are shaken. During the last 3 weeks of April trees of the preferred species, e.g., tilonj, walnut, mehal, willow, on which new webs are observed, or on which the presence of caterpillars is determined by shaking, should be banded (sticky band formula, p. 860), and should be regularly visited at intervals of 2 or 3 days and reshaken. Shaking should be done by climbing (where possible) and by means of a long pole with a hook at the end. Tall trees and inaccessible branches should be neglected, but such trees should be banded. Where caterpillars are very numerous banj and other broad-leafed species eaten by the pest which are close to banded tilonj, etc., should also be banded but not shaken; conifers should not be banded. Time and labour should not be wasted on inaccessible trees. The fallen caterpillars checked by the bands should be regularly swept up and burned. The destruction effected by treating accessible trees is of sufficient practical value.

Cocoons Pupation occurs in a cocoon of white silk powdered with yellow, located in crevices which are cool and dark, e g., under stones, particularly of drainage-channels, in retaining walls and stone edgings, under bridges, in buildings under rafters, planks, joists, etc., and woodwork generally but not ironwork. Practically no pupation occurs in dead leaves, herbage and other soil covering. If caterpillar destruction is not effectively carried out cocoon-destruction must be adopted as a reserve measure.

Lebeda nobilis, Metanastria ampla and **M. grisea,** p 623.

Outbreaks of these species in forests of *Pinus khasya* begin in open mature crops on steep slopes; the young stands are damaged by invasion from the centres of outbreak. Collection of larvae and cocoons is the simplest remedy. For *L. nobilis* on *Myrica rubra* in China destruction of eggs and pupae, poisoning the larvae with lead arsenate, p. 861 and trapping the moths at night are recommended. The ecology of these species needs further study as also of **Suana concolor**, p. 624, **Trabala vishnou**, p. 626, and other lasiocampids which occur with lymantrids as defoliators of *Shorea robusta*.

Taragama dorsalis, p. 624. The regular preventive measures are collection and destruction of the conspicuous caterpillars and cocoons. In a serious epidemic in tea estates hand-collection is insufficient and spraying is impracticable. It is necessary to lop the crowns of shade trees particularly *Erythrina*; lopping is started from the margins of an infested area and proceeds towards its centre and the loppings are destroyed with the caterpillars, etc., in bonfires.

LIMACODIDAE, p. 626

FOR tea gardens it is recommended that regular daily or bi-weekly collections of slug-caterpillars and cocoons should be made throughout the year as a reconnaissance of the incidence and to be forewarned against a sudden epidemic. Collect in the early morning and late afternoon when the larvae are active; drop the catch in tins of oiled water. Sweep up and burn all fallen leaves in infested areas (Hutson, 1932). In lac plantations lead arsenate, p. 861, or tobacco-soap p. 859, sprays are suitable (Glover, 1937).

LYCAENIDAE, p. 632

Virachola isocrates, p. 633: There is no practical experience of control for this pest on wild trees or in forests; treatments advised for pomegranates grown in gardens are:— i. A spray with a contact poison when the fruits have just set in order to kill the young larvae hatching from eggs laid in the calyx of the flower of the unformed fruit. ii. At Kirkee oviposition was prevented by bagging the fruit immediately after fertilisation. Paper bags proved unsatisfactory as they tore badly and paper soaked in paraffin wax allowed water to enter the bag along the fruit-stalk and caused rotting. Cloth bags were effective (cost 4 pies per bag) and if carefully used served for 2 years. iii. At Sangamner about a pound of asafoetida is put in the main water-channel or in a small water-tank generally built near wells and through which the water flows. This is done twice or thrice from the 2nd. or 3rd. waterings; thereby the attack is said to be much lessened.

Niazbeg M., 1914, *Poona Agr. Coll. Mag.*, Pomegranate cultivation at Sangammer.
Caius J. F., 1940, *Journ. Bomb. Nat. Hist. Soc.*, XLII, pp. 13-37, The pomegranate.
Prayag, 1920, *Dept. Agr. Bomb.*, *Bull.* No. 114, The Ganeshkhind Botanical Garden, Kirkee.

iv. On forest land bearing untended pomegranate trees little can be done except collection of the attacked fruits in each crop *before* the butterflies mature and escape; infested fruits should be destroyed at once, or, if saleable, should be packed at once in bags. In some localities the dried seeds extracted from damaged fruits are worth Rs. 10-15 per acre as khat (for curries) and the rind yields a yellow dye.

LYMANTRIIDAE, p. 633

THE reasons for occasional epidemics of **Dasychira grotei**, p. 635, **D. mendosa** 636, **Euproctis** spp., 636, **Lymantria** spp., 638-640 and **Orgyia postica**, 640, in *Shorea robusta* forests have not been investigated.

Lymantria obfuscata, p. 639, is controlled in pure plantations of *Salix* in Kashmir by scraping off or oiling the egg-masses in winter and by spraying with kerosene or crude oil the clusters of caterpillars and pupae on the trunks and branches in May-June. These direct measures are a necessity because the regular flooding of the plantations in summer drives away the soil-dwelling predators which would otherwise keep the pest in check; for the same reason it is abundant in alder woods on river-flats, (p. 840). A suitable egg-parasite should be selected and introduced. In oak forests where pupation takes place on the ground and eggs are laid on rocks and miscellaneous undergrowth it should be possible to protect oak trees by sticky banding the trunks in early spring as for *E. deodarae*, p. 958.

LYONETIIDAE, p. 641

Leucoptera sphenograpta, p. 641: The silvicultural measures advised for *Plecoptera reflexa*, p. 969, should reduce the incidence of this leaf-miner by preventing unseasonal production of new foliage. For outbreaks in shisham nurseries and on newly transplanted cuttings, direct remedial measures may be required. The parasitic control of *L. sphenograpta* in irrigated plantations is good and there are no species missing in the arid region.

NOCTUIDAE, p. 643

MANY species of Noctuidae feeding on miscellaneous trees and shrubs are alternative hosts of desirable parasites and their control follows the principles given under *Hyblaea puera*, p. 960. For sprays and dusts suitable for general use see p. 858.

Cutworms or surface caterpillars

Agrotis ypsilon, **Agrotis** spp., **Euxoa** spp. and other Agrotinae.

W e e d i n g: In a cultivated area grasses and weeds, especi-

ally *Rumex nepalensis* in the mountains, provide food and shelter to cutworms and are therefore undesirable. In a forest nursery, especially a nursery for conifers, the paths, edges to seedbeds, bunds, terrace-slopes, surrounds, disused seed or transplant-beds should be kept clean of weeds. Cutworm damage can be prevented by keeping the nursery site, and particularly the nursery beds which are due to be sown, free from weeds from the time when the female moth is ovipositing (Gardner). Oviposition by moths of the first generation takes place early in summer but the damage to seedlings early in spring is done by cutworms that have hiberated deep in the soil since the previous autumn; hence complete weeding of the seedbeds, etc., from the end of August should be sufficient to ensure the absence of cutworms from beds in which seeds are sown in autumn and germinate in spring; complete weeding 3 to 7 weeks before sowing is desirable for spring sowings.

The principle to bear in mind in arranging the various operations of digging, weeding, pricking out, clearing and lying fallow is that cutworms feed primarily on the weed-growth and, that (i) if this is removed *during* the course of the larval life, the cutworms are forced to attack the tree seedlings, which are unpalatable and consequently are cut down in hundreds in the vain search for nourishment; and, that (ii) if the weeds are removed *before* the larval period, i.e., before a new cutworm generation starts, there is no food available for the young cutworms and consequently they do not survive or grow large enough to attack tree seedlings.

Collecting: Cutworms usually hide themselves in the soil or under debris, leaves, stones and various objects on the ground; they are coloured and patterned obscurely and difficult to detect. They walk about actively during darkness, but if surprised readily drop and curl up. In spite of these difficulties it is always wise to collect and destroy any caterpillars found at any time while working the soil and cleaning the site of nurseries. Look for them specially after rain showers. Digging in the early winter serves to expose hibernating cutworms to frosts.

Irrigation: In nurseries where irrigation or flooding is easily arranged the collecting of cutworms can be facilitated by flooding the area and forcing the caterpillars to leave their tunnels in the soil and come to the surface.

Poison bait: When damage is observed in seed beds use a suitable poison bait. Bran 2½ parts, sodium fluoride, Paris green or lead arsenate 1/8th part, molasses 1/4 part, water 4 parts by weight; mix the dry bran and the poison powder thoroughly in a vessel; dissolve the molasses in water in a separate vessel; gradually add the molasses solution to the bran mixture and stir so as to make a dryish mash or porridge that is loose or crumbling in

the hand. Distribute the bait thinly in small quantities broadcast over and near the affected area, putting it out shortly after sunset just before the cutworms come out to feed at night. (about 2 seers of bait per 100 square yards of nursery beds, or 10 seers dry weight per acre).

Dust and ashes: In the absence of poisons and ingredients for a poisoned bait one remedy is to dust the seed-beds thickly with wood-ashes or a mixture of quicklime and ashes. The measure acts more as a physical barrier to the cutworms than as a repellent; if some succulent leaves and weeds are cut and placed in heaps at suitable places they will serve to attract the cutworms and to concentrate them so that they may be destroyed next day.

Sowings: Numerous small patches in dense weed-growth are liable to damage by a variety of insects in addition to cutworms. For conifers in the northwest Himalayas the patch should be thoroughly well cleaned up and the rubbish burned so as to produce ash over a broad patch. For *Pinus excelsa* the procedure is to prepare the seed-patch as soon as the frost is out of the ground, and to sow the seeds after the rains are well established; for *Cedrus deodara* the sowing would be done in autumn. The long interval between the preparation of the patch and the sowing is essential; it gives better protection against birds and insect pests generally than does a scare-crow or the use of red lead.

Gardner J. C. M., 1935, ***Ind For.***, LXI, pp. 327-329. Note on cutworms damaging deodar seedlings.

Raina J. L., ***Kashmir Govt.***, ***Leaflet*** No. 5, Surface cutworm (in Urdu).

— 1937, ***Mysore Agric. Calendar***, pp. 41, 45. A new method of controlling some important underground pests of crops.

Eublemma amabilis, p. 648. For biological control and remedial measures see under *Laccifer lacca.*

Ingura subapicalis, p. 652. The ecology must be studied before control measures can be devised.

Plecoptera reflexa, The Shisham Defoliator, p. 654.

Beeson, 1938, ***Ind. For. Rec.***, Ent., IV, No. 1, *Guide to the insects of Dalbergia sissoo.*

In natural stands of the gregarious *Dalbergia sissoo* this insect is rarely abundant since on such sites a high subsoil water-level or adequate winter rainfall allows the tree to come into leaf and mature its foliage early in the season. In arid regions it is not injurious if the subsoil water-level is high, e.g., in Shikarpur, Sind, with 3½ inches of rain (7 rainy days) and water at 16 ft. deep. In the Punjab shisham plantations on the other hand it has been a serious pest for decades. The control measures given below apply primarily to irrigated plantations.

Silvicultural measures

Locality: *D. sissoo* should be restricted to areas in which the soil is suitable and which can be guaranteed adequate irrigation to establish the crop. Poor quality and stagnant shisham forms

a breeding-centre for infection of better quality stands. The more xerophytic indigenous species and the exotics used for stocking unsuitable shisham land do not support *Plecoptera*.

Leaf-formation: The newly hatched caterpillar must start life on young foliage, p. 812. Trees which come into leaf early in the season form a canopy of tough foliage which is less likely to be destroyed by the first broods of *Plecoptera* because the proportion of soft expanding leaves in the total foliage is relatively small; and, having matured their foliage, they are practically immune thereafter except when mature caterpillars migrate on to them from completely stripped trees elsewhere. Trees, which do not make a full flush until they have been irrigated or are slow in maturing their foliage after the defoliator has increased, are liable to be completely stripped. Consequently any measures which conserve soil-moisture in the backward areas and achieve leaf-production in advance of irrigation make the individual tree more resistant and reduce the general hazard for the whole plantation.

Irrigation: In the Punjab shisham plantations weather conditions normally bring epidemics to an end by August. The depth and frequency of irrigation affect the progress of epidemics during April–July. During the period 1928–1938 a system of frequently repeated shallow irrigation was favoured, particularly for the regularly attacked and backward stands (*Irrigated Plantation Manual*, 1932, p. 85). When water is given at short intervals the tree responds by producing new foliage at a periodicity which corresponds to the life-cycle of the defoliator. For example, a delta of 3–4 ft. and a frequency of 10 or more waterings during a flow-period of 150–170 days, if uniformly distributed, gives 3–5 inches depth per watering at fortnightly intervals; in the hottest season the life-cycle of *Plecoptera* is 17–19 days with a larval period of 10–11 days; thus the trees produce new leaf just when each new generation starts. When water is given at longer intervals, say 35–45 days, the flush produced after a complete stripping does not coincide with moth-emergence and the pest is locally starved out. It is now recognised that deep irrigation at long intervals is desirable for silvicultural reasons and particularly to induce the formation of deep taproots in the early years. The permanent water-level in shisham plantations varies from about 40–45 ft. in the south to about 15 ft. in the best areas (near Lahore and Daphar); the subsoil moisture-level in the more arid region may rise to 15–20 ft. Modern irrigation technique aims at joining the surface moisture with the subsoil moisture-level, which is obtained by giving deep irrigation in 9″ trenches at long intervals.

i. According to P. N. Deogun the shisham cuttings are planted on the berms of pits 12″–18″ deep and are irrigated at first at intervals of 10 days, which are increased to 20 days later in the growing-season; in the sècond year the interval is further increas-

ed to 2–4 months; root-development is vertical and reaches the subsoil-moisture with phenomenal rapidity, often in one year.

ii. Coppiced regeneration areas should be given good deep irrigation from the outset and pits 15" deep should be dug alongside standards to prevent them dying after the sudden exposure.

iii. Backward crops should be given deep irrigation (9"–10") at intervals of a month or longer according to the water-supply available.

iv. Established crops in the area commanded by one outlet obtain the surplus water not required for poor stands within the area; it may be possible to discontinue irrigation in those stands that have tapped the permanent subsoil-moisture.

Cuttings & sowings: Afforestation by means of wide-spaced root-and-shoot cuttings (or stump planting) is preferable to dense line-sowings in trenches. A thicket of seedlings provides a quantity of tender immature leaves and increases the population of the defoliator per acre considerably more than a crop of cuttings. The resistance of a deep-rooted cutting is higher than that of the individual seedling competing for root-space and its growing-season is longer.

Thinnings: An early thinning produces a more favourable ratio between the pest-population and the quantity of foliage per tree. A thinning that is too heavy or too long delayed produces coppice-shoots and root-suckers which are undesirable.

Underwood & mixture: The presence of soil-vegetation and undergrowth is beneficial because of the eco-climate and shelter provided for useful insects and birds. Very few trees and shrubs appearing naturally in irrigated plantations are food-plants of alternative hosts of *Plecoptera* parasites; they include *Abutilon bidentatum*, *Acacia arabica*, *Cannabis sativa*, *Chenopodium album*, *Melia indica*, *Morus alba*, *Sida rhombifolia*.

Biological control

The parasites of *Plecoptera reflexa*, *Dichomeris eridantis* and *Leucoptera sphenograpta*, p. 641, have been surveyed in the irrigated plantations (Mathur, 1941, *Ind. For. Rec.*, Ent.). The full number of species is found in the older and moister plantations to the north whence the younger and more arid southern areas are progressively colonised, mainly by wind (p. 804); the last to arrive are *Disophrys sissoo*, p. 479, and *Microgaster plecopterae*, p. 484. The distribution of the predators (Carabidae, Formicidae, Mantidae) is irregular and is affected by the courses of the canals and the system of irrigation; flooding and frequent irrigation is detrimental to the ants and ground-beetles whereas deep irrigation at long intervals is much less disturbing. Several species of parasites and predators were imported to deficient localities in 1938 and 1939, p. 848. When the miscellaneous flora of the underwood has improved, species from east and central India should be introduced.

Crows, starlings and sparrows are of no importance in preventing outbreaks; they feed on the surplus population. The resident avifauna obtained by improving the underwood environment forms an important preventive factor.

Mechanical control

Direct measures are expensive and are applicable only to trees of the younger age-classes that come into leaf early along main watercourses and khals; they should be restricted to the first generation of the pest or used as remedies in special cases in later generations. Trapping at light is ineffective. Spraying and dusting are more expensive and more difficult to carry out than sticky banding and shaking.

Sticky bands: Plecoptera mixture, p. 861, is applied in a narrow band round the trunk of a tree and the crown is violently shaken; the caterpillars fall and are prevented from reascending by the sticky band. The cost of banding and shaking an acre with a certain amount of pruning of undergrowth is about Rs. 5. By this method it is possible to destroy enormous numbers of caterpillars, but it cannot be used for extensive areas owing to (a) the inability of the local subordinate staff to patrol the plantation and discover defoliation in its earliest stages, (b) the difficulty of organising prompt action for an emergency, and (c) the insufficiency of the local labour-supply. If banding and shaking is done it should be during the first generation, i.e., normally in the second half of April, on the first trees to come into leaf. Destruction of this generation is far more profitable than destruction of later generations. The trees moreover represent a small percentage of the crop and after the first year when their location is known (and can be checked from the bands of the previous year), the labour and materials required can be estimated and provided as a routine operation.

Prodenia litura, p. 656, invades young teak plantations from agricultural land or taungya-crops; it should be controlled on the field-crops by collection of egg-masses, clipping of leaves carrying colonies of caterpillars, sprays, digging isolation trenches, etc., or prohibiting the cultivation of susceptible crops, e.g., tobacco. A satisfactory poison bait is 10 parts bran, 1 part sodium fluosilicate moistened with water.

OECOPHORIDAE, p. 661

Tonica niviferana, The Semul Shoot-borer, p. 662: The numerical abundance of the borer in a pure plantation of *Bombax malabaricum* is relatively low; a 100 percent infestation in the first year of the crop means a population not greater than the number of plants on the area. Hence direct control measures by tree-to-tree inspection are required, and breeding-material *outside* the plantation is important.

1. Collect and destroy the conspicuous pupae on bark and

leaves in April, May and in July, August in yearling and sapling crops. It is worth while destroying pupae at the rate of a few scores or one or two hundred per acre. ii. Cut back and destroy attacked coppice-shoots of semul stumps in and near the plantation during the latter part of the rainy season and inspect again during the cold weather for later attacks.

PIERIDAE, p. 664

Catopsilia spp., p. 664, **and Eurema spp.**, p. 665: The appearance of the first broods of caterpillars is mainly due to migrating butterflies and regular precautionary patrols of new plantations are needed if remedies are to be used in time to prevent defoliation. Collecting the conspicuous clusters of pupae on the leguminous plants and undergrowth is the simplest measure if spraying with lead arsenate, p. 861, is not undertaken; in a heavy infestation destruction of the eggs by hand is feasible.

PSYCHIDAE, p. 666

Clania cramerii, The Bagworm, p. 668

Biological control: The parasitism and diseases of *C. cramerii* need further study; as the bagworm is a pest in artificial or unstable environments there are possibilities in the improvement of control by parasites. The factors, which reduce damage in sheltered moist situations and in closed crops, need investigation.

In *Casuarina* plantations, where the permanent subsoil water-level is high, the edges of water-holes should be planted with hardy broad-leafed shrubs and trees. This should be a regular prescription for each new annual coupe; the older coupes should be improved concurrently. Such patches of mixed vegetation serve as sanctuaries for beneficial insects and attract the visiting bird-population, prolonging its stay, encouraging nesting and eventually ensuring permanent residence.

Remedial measures: In *Casuarina* and babul plantations half-grown to mature bag-worms are collected by boys from the end of the rains until April in the younger crops and wherever accessible; one cooly can deal with about 10 acres a day; the catch is destroyed by burying it. The early larval stages, which abandon trees as soon as they are felled, can be prevented from climbing the trees in adjoining coupes by sticky band barriers, p. 860. A ground-fire should not be used to destroy mature bag-worms on the ground in the spring; most of the bags are empty and the rest are heavily parasitised.

Outbreaks of bagworms in submontane *Pinus longifolia* forests are due to transitory ecological conditions, p. 807, for which there are no remedies but hand-collection on accessible branches and spraying of larger trees. Collection should be done after the monsoon, as later in the winter and spring the percentage of living larvae in the bags falls much below 50. Heavily defoliated

dying trees do not harbour more living bagworms than green trees, e.g., 100–300 caterpillars, and there is no advantage in felling and burning their crowns. A ground-fire should not be used. Resin-tapping should be postponed on defoliated trees.

PYRALIDAE, p. 670

MANY species of Pyralidae feeding on miscellaneous trees and shrubs are alternative hosts of desirable parasites and their control follows the principles given under *Hyblaea puera*, p. 960.

Dichocrocis punctiferalis, p. 671: On castor oil and cardamom plants the usual remedy is collection of attacked shoots and seed-capsules. Trees in taungya areas are best protected by prohibiting the cultivation of the pest's food-plants in the ya crops.

Dioryctria abietella & Euzophera cedrella, p. 692: Attacked cones fallen from selected seed-bearers and adjacent trees should be collected at intervals between July and next spring and burnt. At all times when cones are collected for seed the infested ones should be destroyed not simply thrown away. Leading and lateral shoots bored by *Dioryctria* should be pruned and burnt.

Hapalia machaeralis, The Teak Skeletoniser, p. 673, is controlled by the measures detailed under *Hyblaea puera*, p. 959.

Hypsipyla robusta, The Toon and Mahogany Shoot-borer, p. 682.

The control of this pest in mahogany and cedar plantations has long baffled foresters and entomologists throughout the tropics and sub-tropics. Absence of borer-damage to these trees is incompatible with rapid free growth in open pure stands; see also pp. 805, 841, 844, 874.

Silvicultural control

Site: New plantation-schemes stand a better initial chance if made in localities where there are no alternative food-plants of the borer, than if made in mixed forests containing numerous flowering trees of *Cedrela*, *Chickrassia*, *Soymida* and *Swietenia*. This locality factor is more important in determining incidence than are climate, elevation and soil. New regeneration areas are liable to be infested from plantations already existing in the vicinity. When there are no external sources of infection the population of the borer in young stands is rigorously limited to the number that can be produced in the green shoots, i.e., a few individuals per plant.

Swietenia macrophylla stands the loss of the leading shoot better than does the small-leafed species, *S. mahagoni*. Differences in the recuperative power of species of *Cedrela* are not well-marked. Wide spacing and free position result in the growth of lateral shoots, which in turn provide the best conditions for the multiplication of the borer; close spacing checks its increase and also assists the attacked tree to replace the lost leading shoot and keep a better shape. Measures which reduce the period of active

production of lateral shoots or which prevent access to them form the basis of silvicultural control, pp. 841, 844.

Shade: i. In Madias mahogany grown pure, wide-spaced and in the open suffers most seriously from shoot-borer attack. Under the shade of the overhead canopy of evergreens, or with the lateral shade given by intermixed plants or by weeds (shrubs and trees) between the mahogany lines, the incidence of attack is less. Mahogany can be raised in plantation with a minimum of damage by shoot-borer (and collar-borer, p. 912) by using a shade-tree-crop and planting the mahogany in dense lines; the shade-crop and the mahogany are both planted at the same time. ii. In Java mahogany grown under cover of an older stand suffers less from borer-attack. Planting in mixture with faster growing species may be expected to provide protection because (a) a mechanical obstacle is offered to the moths searching for the leaders of mahogany in order to oviposit, (b) the slower growth of mahogany during the danger-period of the early years makes them less attractive to the moths and less suitable for the development of the caterpillars, (c) the branching of attacked saplings is restricted for want of space. Species suggested for mixture with mahogany in Java are *Cassia siamea*, *C. timorensis*, *Melochia umbellata*, *Leucaena glauca*. iii. In British Honduras where mahogany is attacked by an allied species, *Hypsipyla grandella*, it has been found that overtopping the mahogany by weed-growth is beneficial in preventing shoot-borer attack. The mahogany seed is dibbled in lines with maize at 10 × 10 ft. intervals and the area is abandoned after the first crop has been harvested; the young plants are then sufficiently established to compete with weed-growth, which very quickly closes the canopy. Tending consists in removing climbers. Mahogany grows well under the canopy of secondary growth and heavy cleaning is not only undesirable but disadvantageous because it is nullified by borer-damage.

Mechanical control

Pruning: Cutting off the attacked shoot while it contains the borer is a means of destroying the pest in the first 2 or 3 years of the crop. In the tropics this must be done throughout the year at intervals of a month or so in order to include all attacks. Pruning of this severity produces abundant new shoots and eventually results in increased borer-attack and bushy plants; it is useless as a remedy in open or lightly shaded crops.

Thinning: By regular thinnings in young stands of pole size and later which are lightly attacked, the badly shaped individuals can be removed. In stands which are heavily attacked, on the contrary, thinnings are not beneficial. Badly attacked plantations of *Cedrela toona* in Bengal which were abandoned were found later to contain a satisfactory proportion of useful stems.

Sack-banding: In north India and Burma, where *H. robusta* passes 2 generations in the flowers and fruits of *Cedrela*

toona, the matuie caterpillars can be trapped in bands of sacking tied round the trunks of flowering trees. The population of these generations is many times that of a shoot-boring generation and its destruction very considerably reduces the initial incidence of attack on shoots. For further details see Beeson, 1919.

Biological control: Although several species of parasites of *H. robusta* exist in the Indian region, including some attacking the larva inside the shoot, it in unlikely that any can be used advantageously. At a tolerable degree of damage the borer-population per acre is so low that parasites cannot maintain themselves at a higher incidence than about 10-20 percent; normally they are almost entirely absent. An appreciable amount of help is obtained from predators derived from weeds and shade-crops.

Margaronia caesalis, p. 688, has not been investigated but it reacts to shade conditions very much as does *Hypsipyla robusta* and is probably controllable by similar measures.

Margaronia pyolalis, p. 689: The introduction of *Cedria paradoxa*, p. 475, is the only likely measure now known. It is remarkable that mulberry grown in India and Burma for sericulture is not defoliated by *pyolalis*, possibly because the plant is regularly plucked and pruned.

Sylepta derogata, p. 693, is controlled on cotton by collecting the leaf-rolls in a bucket of oiled water and by spraying or dusting; by cleaning up the land after harvesting the cotton and by exterminating *Sida cordifolia*.

Terastia egialealis, p. 693, on shade trees of *Erythrina* is probably an indicator of poor vitality; it is not controllable by light pruning.

SATURNIIDAE, p. 695 & SPHINGIDAE, p. 617

WHEN species of these families appear in abundance on forest trees the predisposing causes are abnormal and until they have been specially investigated there is no other remedy than collection of the large caterpillars and cocoons or pupae.

TINEIDAE, p. 701

Gerontha captiosella, p. 702, multiplies chiefly in dying or dead standing trees and rarely breeds in newly felled timber, p. 871; control is obtained by prompt removal and conversion of dying and stagheaded trees.

Melasina spp., p. 703, have not been studied enough to indicate possible control measures.

Tinea pellionella, p. 703: See p. 877, *Gastrallus*, p. 914, *Anthrenus* and p. 927, fumigation.

XYLORYCTIDAE, p. 705

Nephantis serinopa, p. 706: On the biological control of

the coconut caterpillar see Jayaratnam T. J., 1941, *Trop. Agr.*, XCVI, pp. 3–21, and reference p. 706.

ACRIDIDAE, p. 711

DAMAGE by grasshoppers of various genera to cultivated areas such as a nursery, patch regeneration, rab, taungya or plantation is due to hoppers or adults that have invaded from surrounding vegetation. The best method of dealing with the invaders is poison baiting; if the danger is anticipated, strips of ground 5 yds. wide should be left unweeded so as to act as concentration sites. Bait each trap strip promptly as the hoppers gather in it and repeat as needed. Where strips are not available bait the margins of the cultivated area. A suitable formula is given in page 978. For ordinary infestations the bait should be spread thinly at a scale not exceeding 20 lbs. an acre, even where grasshoppers are abundant in rank vegetation; a scale of 5 lbs. an acre often gives satisfactory results. Baiting should be done where grasshoppers are visible and should be continued throughout the season where-ever they are present. The moisture in the bait is very attractive so it should be put out early in the day and be renewed when it has dried.

Aularches miliaris, p. 713: Adult grasshoppers, when mating during October and November, are sluggish and easily caught and destroyed. Locate the places where eggs are laid and dig or plough the soil during November–March, thereby exposing the egg-masses to natural destructive agencies. Inspect egg-laying places in February, March to discover the newly emerged hoppers; they are weak and easily killed by spraying or sweeping into trenches, etc., when only a few days old. A suitable spray is soap solution; for hoppers up to a fortnight old the formula is 1 lb. soap to 8 galls. water; for hoppers 1 inch long use 1 lb. in 6 galls. When they have grown to 1½ inches long spraying is impracticable on account of their greater activity and resistance. Where possible drive the hoppers into drains or pits or up against a bank or wall so as to spray more effectively and economically; use a fine mist-nozzle and wet the hoppers thoroughly. (Hutson, 1935).

Hieroglyphus banian, p. 714: On rice land the chief remedy is destruction of eggs in the autumn. The egg-masses are concentrated on the bunds of paddy fields; scrape the sides and tops to a depth of 2–3 inches soon after harvest so as to cut up or expose the egg-masses to destruction by weather. In fields of ratoon canes scrape the sides of the ridges with a light plough. If infested cane-land is left fallow, the whole field should be ploughed just after harvest so as to break the ridges and expose the eggs to the hot weather sun. In the rains the newly emerged hoppers should be handnetted or driven or sprayed as advised for *Aularches* (Rao and Cherian, 1940, *Ind. Farm.*, p. 495–498).

Locusts, p. 710, Schistocerca gregaria, p. 717

1939, Rao V. R., *Agr. & livestock Ind.*, IX, pp. 233-247, Locusts in India and their control — 1941, *Methods of locust control recommended by the Imp. Counc. Agr. Res.*, 2nd. ed , pp. 17 figs 6.

Control of locusts at the source of migrations, if necessary by international action, is the logical solution. Nevertheless it is possible and profitable to adopt remedial measures for local application on the fringes of advancing swarms and at new temporary breeding-centres.

Flying locusts: The adult locusts can be destroyed at night: i, beat them or sweep them up on bare ground, ii, burn them when assembled on bushes, iii, shake them from the branches of trees, iv, collect them by hand from valuable crops. And by day: v, disturb or drive them away from crops or vi, put out poison baits, vii, spray vegetable or fruit crops with neem leaf solution, p. 862, viii, catch the pairing locusts and crush or burn them, ix, crush the ovipositing females.

Eggs: i, Locate the breeding-grounds by patrolling or offering rewards for information, ii, ring-fence the oviposition grounds, iii, flood the ground if possible, iv, dig or plough up the soil containing eggs, v, protect crops within the ringed area by subsidiary trenches.

Hoppers: i, broadcast poison-baits in infested fields, ii, spray or dust crops likely to be attacked, iii, drive hoppers into trenches or pits.

Poison bait: The formulae are bran 50 parts, sodium fluosilicate (p. 865) 1 part, and molasses, gur or rab, 2 parts or salt 1 part; a little amyl acetate may be added to make the bait smell attractively. Thoroughly mix the dry bran and dust, then add a strong solution of the molasses and finally add water enough to make the bait moist but not sticky or lumpy; scatter the bait very thinly and evenly using a haversack or grain sack slung over the shoulder. One maund suffices for 1¼ to 1½ acres.

Kerosene soap emulsion, p. 858, is a suitable contact spray for hoppers.

Ring-trenches: A breeding-ground is isolated by digging round it a trench 1 ft. wide and 1½ ft. deep, with vertical or undercut walls free from roughness which may help hoppers to climb. A trench may be reinforced by strips of shining American cloth 6 ins. wide nailed along the top 6 inches of the outer wall; sheets of smooth metal 1 ft. wide may be laid so as to overhang the outer edge of the trench.

Ring-fences: Where satisfactory trenches cannot be dug a fence of oil-cloth strips 6 ins. wide or metal sheets 1 ft. wide is erected. The material is supported vertically by means of iron spikes (see I.C.A.R. pamphlet for details).

Drives or kheddahs: To drive an army of hoppers

from open country into trap-trenches barriers are erected on the flanks of the drive, converging towards the trench at the apex; for the flanks use strips of cloth about 25 yds. long and 44 ins. wide with a 6 inch band of oilcloth sewn on at the top edge which is strengthened with a stout cord; the barrier is made of a series of lengths of the cloth supported vertically by $\frac{1}{2}$ inch bar-iron rods driven 6 ins. into the ground so that there is a vertical wall 3 ft. high and 6 or 8 ins. overlap on the ground weighted with stones or earth.

BLATTIDAE, p. 719

Periplaneta spp., Cockroaches, p. 720

SODIUM fluoride, p. 862, is the most effective poison for cockroaches; as a stomach poison it is slow but sure. The places where cockroaches shelter during the day, such as crevices and dark corners, in cupboards, behind boxes, etc., should be located and dusted thinly and uniformly with dry powdered sodium fluoride. For cracks and cavities not accessible to dusting a bellows or air pump or blower should be used to blow the dust inside. If used in kitchens or storerooms the dust should be applied in the evening and left overnight and swept up in the morning before food is prepared. Tables and shelves, etc., should be washed after the poison has been used. In libraries and office record rooms the dust may be sprinkled on shelves behind the books and files and left without danger until the crockroaches have all been killed off. Sodium fluoride can be used pure, or mixed with an equal quantity of flour to act as a bait.

Borax, p. 884, is poisonous to cockroaches but acts more slowly than sodium fluoride; it is usually exposed mixed with an equal quantity of cocoa or chocolate powder in small heaps.

Pyrethrum powder, used in the same way as sodium fluoride, is almost as effective. It quickly stupefies the roaches so that they can be swept up and destroyed. Pyrethrum is a safe remedy and is not injurious to man or domesticated animals.

Poisonous pastes containing phosphorus are specially effective in very damp climates. The paste is spread on stiff paper or flexible cardboard which is rolled into a cylinder and tied with string; the cylinders are placed behind shelves, cupboards, etc., and in places where the roaches congregate.

Direct spraying with pyrethrum-kerosene oil mixtures (various commercial brands of fly sprays) is effective if the roaches are hit and really wetted by the spray.

To protect the backs of books in open bookshelves use an alcoholic solution of boric acid, which does not tarnish gold lettering, or mercury bichloride, p. 877.

GRYLLIDAE, p. 721

Gryllotalpa spp., Mole-crickets, p. 722

IF land destined for the formation of a nursery or plantation is known to be infested with mole-crickets it should be ploughed or hoed to a depth of 9 inches at the period of pairing and egg-laying and cleaned of nests and adults. Seed-beds in nurseries may be isolated (a) by planking or battens 4 or 5 inches wide, half above ground and half below ground or (b) by trenches.

Traps; Sink earthenware pots with wide but constricted necks at intervals of a yard or two a little below ground-level or at the bottom of trenches in order that mole-crickets may fall into them. The traps work better if they are connected up with battens a few inches high sunk slightly into the soil, for the insects which run about on the surface at night tend to follow alongside the obstruction and are led straight into the traps where they can be destroyed subsequently. Pots may be usefully sunk in trenches between seed-beds.

Flooding: In fairly stiff soil (not loose sand) mole-crickets can be driven out of their tunnels by pouring water into the openings of freshly made tunnels. If no watering-can is available some sort of funnel or pipe or hollow bamboo should be used. It is beneficial to add to the water weak oil-emulsion, p. 858, or in safe places turpentine or kerosene can be used. The work is best done on a sunny day following after rain so that the inhabited tunnels can be distinguished from the empty ones. The crickets are caught and killed as they emerge from the tunnels. Where irrigation is available general flooding will bring out the insects but they are active swimmers and can stand submersion for a long time.

Nests: In permanently cultivated ground the nests with eggs or young should be traced and destroyed in midsummer by following up the tunnels or hoeing up the ground generally. The egg chambers are found at a depth of about 4 inches at the end of a short tunnel.

Baits: A half pumpkin placed with the cut side down and covered with cut weeds and left overnight may yield mole-crickets next morning in places where there is a shortage of shelter and food. Poison baits are sometimes satisfactory where other methods connot be used, i.e., Paris green 3 or 4 parts, flour 100 parts, gur or molasses 1 part, made up into a dry mixture and spread in a shallow trench along the edges of a nursery or sown patches, and scattered lightly over the entire bed or patch at about 25–30 lbs. to the acre. The standard sodium fluosilicate bran mash, p. 978, may also be used.

Gryllodes sigillatus and Gryllulus domesticus, pp. 722, 723: A poison bait containing sodium fluosilicate 1 part, bran 50 parts, gur 2 parts, is effective against house crickets. In dry weather a

combination of a dry bait composed of 1 part sodium fluosilicate to 8 parts of flour, and wet bait consisting of a saturated solution of sodium fluosilicate in water with traces of sugar and vinegar may also be used. A sponge or cotton wool pad is soaked in the wet bait and exposed near the heap of dry bait at night.

For use against *Gryllulus domesticus* in the open fields or nurseries a suitable poison bait is 1 part sodium fluosilicate, 20 parts rice or wheat bran, 1 part molasses and enough water to moisten the mixture. The bait is scattered over the affected area in the same manner as for control of locusts. Material for treating one acre for one dose costs about Re. 1. Crickets die within 12 hours. Swarms of crickets in heavy infestations need to be dealt with by means of barriers and trap trenches as for locusts. See *Agric. Livestock, India*, 1939, IX, pp. 692–694.

ALEYRODIDAE, p. 731

WHITE flies on forest trees must be controlled by agricultural methods, i.e., spraying with rosin soda, p. 859, or fish oil-rosin soap, p. 858; see references pp. 731, 732.

APHIDAE, p. 732

APHIDS which feed exposed on succulent shoots are controllable by spraying with the soap emulsions and tobacco solution given on pp. 858, 859. The ecology of the gall-formers has not been studied enough to indicate control measures.

Eriosoma lanigerum, p. 734: The colonies of woolly aphis living exposed on branches and stems of apple trees are sprayed with fish-oil-rosin soap, p. 858, with the fish oil replaced by *Bassia latifolia* oil. The colonies infesting the roots are fumigated with paradichlorobenzene, p. 864, during December at the rate of ½ oz. per nursery plant, 1–2 oz. per 5–15 year old trees and 4 oz. per 20–25 year old trees. Open up a 4″ deep circular trench of 5 ft. radius round the tree and scatter the insecticide therein and refill with earth; the fumigant works for 2 or 3 months in winter and 1 month in summer. The colonisation and distribution of *Aphelinus mali*, p. 494, is in progress in the Punjab and U. P. (*Progress reports, Hill Fruit Research scheme*, Chaubattia, U. P.).

CAPSIDAE, p. 736

FOR the control of **Helopeltis theivora** in tea gardens by manuring see p. 816 and Andrews (refce. p. 737). Against *Helopeltis* spp. in Java burial of oviposited prunings, spraying with soap-solution, hand-collection and removal of alternative food-plants are advocated.

CERCOPIDAE, p. 737

Machaerota planitiae, p. 738: The badly attacked branches of lac host-trees should be cut off and burned.

CIMICIDAE, p. 740

CONTROL by cleanliness, washing down rooms with crude oil emulsion, and by using pure pyrethrum powder or leaves of *Pterospermum acerifolium.*

COCCIDAE, p. 740

VIGOROUS healthy growth is the best preventive against coccid attack; see p. 873.

Aspidiotus orientalis, p. 742: Spray with lime 35 lbs., sulphur 70 lbs., water 100 galls. Warm the water and add the whole of the lime as quicklime; when the lime is slaked, add the sulphur and heat the solution, stirring until it boils; keep it at boiling point until it becomes dark brownish-yellow. If possible prune the trees before spraying and use the liquid tepid or warm, and spray through a lime-sulphur mist-nozzle on a calm day (for details see Glover, 1933).

Aspidiotus perniciosus p. 742: In the Punjab and Kashmir it is effectively controlled with oil emulsion, using diesel oil and potash-fish-oil soap, p. 858; one spray in November-March is usually enough. In the Punjab hills 8-64 trees can be sprayed for Rs. 1; in Kashmir 4-43 trees.

Fotidar M. R., 1941, ***Ind. Farm.***, II, pp. 234-237, pls. 2, The San Jose Scale and its control in Kashmir (and references p. 743).

Dactylopius spp., p. 744: See biological control of prickly pear, p. 853.

Drosicha spp., p. 747: O r c h a r d s, etc.: For the protection of fruit and avenue trees apply sticky barriers to the trunks, pp. 860, 861, in the early cold weather and keep them fresh until April; kill the nymphs congregated at the barriers by spraying with fish-oil-rosin soap, p. 858, or brushing them into a vessel of oiled water. Destroy the eggs between July and October by sweeping up soil-litter around the base of a tree and burning it, and removing the soil for 6 inches depth, replacing it with fresh soil. Foliage and branches invaded by mealy bugs should be sprayed with fish-oil-rosin soap.

H o u s e s: Dwelling houses are invaded by *Drosicha* spp., particularly *mangiferae*, when they are in the mature 2nd nymphal stage usually in March, April in north India. The best protective measure is to prevent breeding of mealy bugs in the host-trees in the compound by (a) sticky-banding the trunks just before the season of migration to the crowns, and (b) digging a shallow trench around the base of the tree with the outer wall steep in order to prevent the female bugs from wandering after they descend from the crown; collect and kill the bugs so trapped and cultivate the soil under the tree after the monsoon in order to destroy the eggs in the soil. To prevent bugs entering buildings it is necessary to keep doors and windows closed in March-April

or fit wire gauze frames. Or use sticky bands along the risers of steps and doorsills. Possibly gutters, drainage-channels, verandahs or edges of paths can be utilised to isolate the building. Where a sticky barrier cannot possibly be allowed a band of cotton wool or fluffed raw cotton can be used. A length of thread or string pulled taut between 2 tacks is enough to keep the band in place.

Laccifer lacca, The Lac Insect, p. 751. For the control of the lac insect, i.e., its cultivation, see *Lac cultivation in India*, 2nd., ed. 1937 and references p. 755.

Control of lac predators: Damage to lac crops is of two kinds (a) weather conditions such as heat, frost, etc.,—to faulty cultivation, e.g., incorrect pruning, infection of host-trees with unsuitable strains of lac, wrong cropping methods,—to mortality due to overcrowding of lac larvae; losses due to these causes amount to 30 or 40 percent of the original settlement. And (b) destruction by insect enemies of *Laccifer lacca*, the parasites and predators; losses due to these causes also amount to approximately 30-40 percent of the lac cells. The regular parasites include 8 species; the average losses amount to about 5 percent, and an average maximum of about 10 percent of the lac cells. Predators include 6 species of which 2, *Eublemma amabilis* (Noctuidae) and *Holcocera pulverea* (Blastobasidae) are regular and serious. The average losses amount to 30-35 percent of the lac cells. Three species of hyperparasites affect the lac parasites; the average hyperparasitism is about 4 percent with an average maximum of only 10 percent. In view of this low percentage of natural hyperparasitism and the small amount of damage done by the lac parasites, biological control of the parasites is not of practical importance.

Biological control in the lac industry is therefore a matter of controlling the lac predators. These are about 10 indigenous species parasitic on *E. amabilis* and *H. pulverea* and of these only *Microbracon greeni* (an ectoparasite of the larva of *E. amabilis*) shows promise of usefulness for biological control. Another species of *Microbracon*, *M. hebetor*, has been discovered; it does not occur naturally in lac-growing districts but has been experimentally induced to parasitise both *E. amabilis* and *H. pulverea.*

Investigations are now being undertaken by the Lac Research Institute in localities where palas or kusmi lac is grown to determine (a) the effect of periodic releases of *M. greeni* on its population-density and on the percentage of hosts parasitised, (b) whether *M. hebetor* can be artificially introduced and established, and what is its natural population-density, (c) whether the parasitism of the predator by *M. greeni* can be maintained by means of adults transferred from one area to another in brood lac, and (d) whether *M. hebetor* can be transferred by means of brood lac. Experimental liberations of both species in Bihar started in 1939.

Glover P. M. and Gupta S. N., 1939. *Ind. Jl. Agr. Sci.* IX, pp. 523-530. The practicability of biological control in the lac industry.

Cultural and mechanical control: Lac intended for use as

brood should be cut as near to the time of swarming as possible, never more than 1 week before, to get the best results. Select healthy lac, showing the least amount of parasite and predator attack and reject damaged sticks. Remove the lac sticks tied to trees as brood not later than 3 weeks from the date the swarming began; 2 weeks is generally long enough for infection. Give up the practice of leaving uncut lac on the tree for natural infection or at least avoid it in October, November. All lac cut from the tree and not required for brood and all brood lac after use should be scraped from the stick at once; remove the scraped lac from the vicinity of lac infected trees.

The storage of lac leads to a falling off in quality and quantity on manufacture. The ideal treatment of lac after cutting is to sell it as soon as possible to the manufacturer for immediate washing and conversion into seedlac. This satisfactorily eliminates the parasites and predators. The seedlac should either be exported as such immediately or be converted into shellac and shipped to a cool climate (Glover, 1937).

Lecanium longulum, p. 755: Spray with kerosene oil emulsion, p. 858, using karanj, *Pongamia glabra*, soap. For use on suberised or hard-barked twigs the stock solution need be diluted with only 5 or 10 parts of water instead of 20. Spray in the evening or on cloudy days and not in the full heat of the sun.

Pulvinaria maxima, p. 756: Prune badly infested trees preferably at the time the egg sacs are deposited and spray with fish-oil-rosin soap, p. 858, at a strength of 1 lb. soap in 8 galls. water; repeat the spray a fortnight later when the larvae swarm; neighbouring trees apparently not attacked should be given a prophylactic spray. Burn or bury the prunings; sweep up and burn the litter around the base of an infested tree.

Ripersia resinophila, p. 756: Heavily infested pines should be felled at ground level, and lateral branches should be cut off trees less attacked and likely to recover. Take the small trees and prunings to a clear space some distance away from young pine and sheltered from winds and pile them in close stacks. The parasites and predators will emerge and fly away; the mature coccids will die and the larvae will perish while wandering in search of pine.

Saissetia spp. p. 757: Spray with a contact poison, p. 858.

FULGORIDAE, p. 758

No control measures have been devised for any fulgorid attacking forest trees. The species of *Pyrilla* attacing sugarcane in India have been studied for the past 30 years and elaborate research on their control is still in grogress.

JASSIDAE, p. 762

Measures for the control ot Jassidae on trees in forests have not been devised; they are controlled on agricultural or fruit

crops on the following lines.

Bythoscopus: Pyrethrum powder, p. 859, or pyrethrum with sulphur in 50 : 50 or 25 : 75 has a good toxic quality.

Empoasca: Bordeaux mixture, p. 859, has a good residual effect and a delayed toxicity on some species although not acting immediately. The leaf-hopper turns yellow and becomes paralysed probably by ingestion of copper compounds formed in the plant sap.

Idiocerus spp., p. 763 : Spray mango trees with rosin soda or fish-oil-rosin soap, 1 lb. in 10 galls. p. 858, beginning as soon as the first flowering shoots appear and repeating weekly if further broods of hoppers appear. Irrigate the trees when the fruits have set or intercultivate to conserve soil-moisture. Or dust the inflorescences with sulphur 2 or 3 times at fortnightly intervals.

Jassus indicus, p. 764. The ecology of this species needs study; its control in sandal forests is likely to be found in conditions governing migration from agricultural land into forests and the destruction of its alternative food-plants, and therefrom the value of isolation-barriers and selective thinnings.

Nephotettix, p. 766: Oil the surface of the water of flooded rice-fields and trap at light.

MEMBRACIDAE, p. 768

No control measures have been devised or any membracid attacking forest trees.

PENTATOMIDAE, p. 769

METHODS used is agriculture are usually collection of eggs and bugs by hand or net or oiled water, and spraying with a strong contact poison, p. 858.

Cyclopelta siccifolia, p. 771 : Collect the colonies congregated on twigs.

Nezara viridula, p. 772: Collection by hand or net is the usual remedy. In Australia the liberation of an egg-parasite, *Microphanurus basalis*, is under investigation.

Tessarotoma javanica, p. 733 : The nymphs and adults being large and conspicuous, practically the whole population can be destroyed on lac-hosts by hand-collection.

Urostylis punctigera, The Champ Bug, p. 773

PREVENTIVE MEASURES

Site: In selecting sites for plantations of pure *Michelia champaca* avoid natural forests containing a high proportion of the alternative hosts of *Urostylis punctigera*, i.e., trees of *Magnolia pterocarpa*, *Michelia excelsa*, *M. kingii*=(*M. montana*), *M. oblonga* and *Talauma hogdsoni*; and possibly other Magnoliaceae not yet incriminated. In forests containing only scattered trees of these species a zone around the boundaries of the proposed plantation should be cleared previously of saplings and poles of

these species and the stumps should be dressed or poisoned so that coppice-shoots are not produced. The minimum effective width of the zone must be determined by experiment; in view of the gregarious habits and slow dispersal of the bug it is probable that a relatively narrow zone will provide the required barrier to infiltration from natural forest.

M i x t u r e: The localised colonisation and slow spread therefrom observed in some pure champ plantations indicate that mixture of champ with other non susceptible species will appreciably prevent intrusion and will facilitate the operation of direct remedial measures if invasion does occur. The most suitable form of artificial mixture is probably by bands of about 5 lines or by planting in small blocks or plots randomised with blocks of other species. Here again experimental trials are needed.

REMEDIAL MEASURES

Direct control: Young plantations should be inspected regularly in order to discover when the bug enters and establishes colonies large enough to cause appreciable damage. Direct remedial measures should be used to destroy or restrict the centres of multiplication and spread. In practice nothing can be done against adult bugs scattered sparsely throughout the plantation and constantly on the move. Operations should be concentrated on (a) early stage nymphs clustered on young foliage and buds at the ends of terminal and lateral branches, (b) the later stage nymphs after they have migrated to the bark of the stem and branchlets.

S p r a y i n g: A suitable mixture is nicotine sulphate, 1 pint with soap 4 lbs in 100 gallons of water; a standard oil emulsion may be used instead of soap. (p. 858). In an emergency a nicotine-soap solution can be made by steeping 1 seer country tobacco leaves in 14 bottles, (24 ounce bottles) of water for 24 hours, straining the liquid, adding $\frac{1}{4}$ seer of sliced cheap country soap, and mixing thoroughly. The stock solution can be diluted with 4–5 times its volume of water to make 3 or 4 kerosene tins (12 14 gallons) of spray mixture (also p. 859).

A hand pump sprayer or A R P stirrup pump with extension tubes can be used with a jet nozzle for working in dense plantation under a closed canopy of obstructing branches and foliage, or a mist nozzle for working above the crowns of young trees. Two operators are required, one for the pump and one to carry the spray and water containers. Spraying is only effective on accessible colonies of young nymphs and is worth doing only on the spring broods. It is of very little use to spray adult bugs.

S m o k i n g: In the presence of smoke *Urostylis* nymphs drop readily from the foliage or are driven from the leaves to the main stem and thence fall to the ground. Damp thatch grass or straw or cowdung cakes are burnt to produce the smoke. Smouldering cowdung contained in a tin attached to a bamboo

pole can be elevated to the crowns of young pole crops to deal with colonies of bugs undisturbed by smoke-fires on the ground. The fallen bugs can be sprayed, swept up or prevented from reascending by smearing a sticky band on the boles of the trees. This remedy is useful during the season of heavy rains when spraying of foliage is most difficult.

Biological control: On the first appearance of *Urostylis* in a plantation material should be collected to decide if the egg-masses are parasitised by *Pachyneuron pentatomivora* (p. 514) and if the predator, *Calvia tricolor* (p. 242), is present. Where these natural enemies are missing they should be introduced under a properly planned scheme and in sufficient numbers to establish initial colonies in one season. A simple method is to pick champ leaves bearing egg-masses and put them directly in a tin; take the tins to the affected plantation and stand them in a vessel or tray of water. When the beetles or parasites mature they fly away but the bugs cannot escape through the water.

TINGITIDAE, p. 785

Teleonemia scrupulosa, The Lantana Bug, pp. 785, 851 for biological control.

SIPHONAPTERA, Fleas, p. 787

FLEAS cannot breed in the rooms of houses that are regularly cleaned. Sweeping as done with the usual sweeper's broom is totally inadequate; floors should be washed with soap and water and if full of cracks should be sterilised with kerosene or disinfectants. If dogs or cats are kept in houses the mats, carpets or upholstered furniture frequented by them should be frequently put out-of-doors in hot sunshine; if dogs are kept in kennels the bedding and soil should be treated with common salt or kerosene. Animals' coats should be dusted with pyrethrum and washed with carbolic soap.

THYSANOPTERA, Thrips, p. 788

ONE of the best sprays for thrips is tobacco, p. 859, e.g., tobacco leaf and refuse ½ seer, soap 2 chhitaks, water 1 gall., diluted with 4 galls. water; alternatively nicotine sulphate ¼ seer, soap ½ seer, water 100 galls. Decoctions of leaves of *Calotropis procera* or *Melia azadirachta* with soap are useful substitutes. There is no practical experience of remedies for gall-forming thrips on forest trees.

THYSANURA, Silver Fish, p. 792

BOOKS, papers, fabrics, clothing, etc., may be protected from **Lepisma** by keeping in closed receptacles with naphthalene dust. The vapour of naphthalene, camphor, etc., kills the insects, but pieces of these substances strewn on open shelves or boxes

are not so effective in keeping them off. The backs of exposed pictures, photographs, etc., may be painted with the deterrents given on p. 877. Since they breed very slowly, periodic cleaning out of book-shelves, boxes, etc., with the destruction of the disturbed insects is an obvious practical remedy.

A suitable bait for silver fish is a mixture of 1 part of sodium fluoride or barium fluosilicate, 3 parts of wheat flour and 1 part sugar, used as a powder or with enough water to make a thin paste by boiling. The paste is poured on to small pieces of flexible cardboard or paper which after drying are rolled into cylinders with the paste inside. The cylinders are distributed in places frequented by silverfish, i.e., on shelves, behind books and picture frames, in drawers and cupboards. Cupboards should be sprayed with fly spray when the contents are removed for drying and airing.

How to send Specimens of Insects and Insect-damage to Dehra Dun

To be sure of getting an identification always send plenty of material, i e., dozens of specimens of the insect with samples of the damage done by it. Send living material of larvae, grubs and caterpillars in preference to killed and preserved material.

Despatch : Specimens of small weight should be sent by parcel post NOT registered, and heavy specimens should be sent as railway parcel by passenger train; send the railway receipt by the same post. Address—**Forest Entomologist, Forest Research Institute, New Forest P. O., Dehra Dun, U. P.**

Labelling : Every consignment of specimens of living or dead insects, or of damaged material should be accompanied by a label, giving (*a*) the locality of collection, (*b*) the date, (*c*) collector's name, (*d*) name of tree, in such a way that no confusion is possible when several species are sent. Spirit specimens should have labels inside the bottle or tube, written *in pencil* or in *Indian ink*, but not in ordinary office ink.

Moths and butterflies : Kill in a cyanide bottle, or by fumes of benzene or ammonia, or by squeezing the body (thorax) between the fingers from the underside after folding back the wings; avoid damaging the legs, antennae, scales, etc., Do not attempt to pin or set moths unless expert. Butterflies and moths should be put into triangular envelopes with their wings folded together over their backs. The envelopes are made by taking an oblong piece of paper (almost any sort will do if not too stiff), and folding across diagonally so as to make two flaps overlapping an inch or so. Fig. 1. Double one flap up, the other down, as figure 2. Several envelopes containing the moths may be packed flat in a box without crushing. Write the data on the envelope flap.

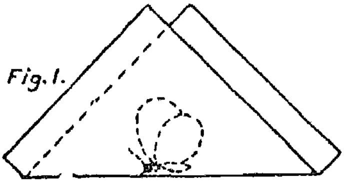

Fig. 1.

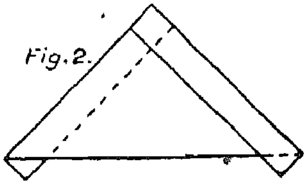

Fig. 2.

Beetles and other hard-bodied insects : Kill in a cyanide bottle or drop directly into 70 percent alcohol or methylated spirit. Kerosene or petrol or oil should not be used. Failing spirit or cyanide, kill by dropping into boiling water. After drying wrap each specimen separately in a twist of tissue or other soft paper and pack in a box without crushing tightly yet not so loose as to rattle about. Do not use cottonwool for wrapping up dead insects.

Termites : see *Indian Forest Records*, Ent., IV, No. 1. (1941).

Grasshoppers and bugs : Kill in a cyanide bottle and wrap in twist of tissue paper and pack in a box as for beetles. They may be put direct into alcohol but this destroys the colours and makes identification difficult.

Larvae, grubs, maggots, caterpillars, etc. : Drop into boiling water for a minute or two and transfer to spirit. If put directly into spirit the specimens become blackened and distorted. Send larvae, etc., alive whenever possible. If medicine bottles or tins are used they should first be thoroughly cleaned. The cork may be sealed with candlewax or beeswax but *not* with sealingwax. Bottles or tubes of spirit should be packed in wooden boxes with crumpled paper, wood shavings or dried grass.

PACKING LIVE INSECTS FOR REARING AT DEHRA DUN

Caterpillars and other defoliators : Leaf-eating caterpillars should be sent with a supply of food for a long journey. They should not be sent in bottles or glass tubes or small tins, but in wooden boxes. A large mass of green vegetable matter should not be sent tightly packed as it is likely to ferment. It is advisable to prepare a small wooden box with a lid and take it into the forest and collect and pack the insects on the spot. Freshly picked twigs and shoots of the food-plant should be tied in small bundles and fastened by nails to the sides of the box, so that nothing can shake loose ; absorbent layers of paper or of dry grass should be placed at the bottom and the top. Very large leaves, such as those of teak, are best packed loosely in a mass of dry grass in a box. Wooden boxes do *not* require holes for ventilation purposes. Avoid keeping the boxes in the sun and despatch them by rail without delay.

Wood-borers : Boring grubs of shoots and branches and boles should be sent in the wood in which they are feeding. Their presence is indicated by holes in the bark, ejected wood-dust and

fibres, etc., and can be confirmed by cutting up similarly affected logs or branches to discover the exact position in which the larval galleries occur. Logs two feet long, or multiples of two feet, are of the most convenient dimensions to send. Small branches and saplings are best tied together in a bundle and packed in dry grass and sacking and enclosed in a long wooden box, or a bamboo tube. Larger logs and sections of tree-trunks two to three feet in girth should be wrapped in damp grass, palm leaves, the bases of plantain leaves, moistened jute fibre, etc., and sewn up in sacking, or canvas.

Larvae living in soil: Cockchafer grubs, cutworms and other soil-living larvae should be sent separately, each in a small box or tin full of soil, but there must be no empty space. They require no food-material and no arrangements for ventilation.

Specimens of damage: (*a*) Specimens of defoliated leaves and shoots, damaged seedlings, etc., should be pressed flat between sheets of blotting paper, as botanical specimens, and packed in stiff cardboard. (*b*) Scale-insects on twigs, galls, etc., and damaged seeds or fruits should be sent in spirit. (*c*) Wood specimens large and small may be packed in sacking or paper.

COLLECTING FOR THE INSTITUTE

Tubes, pins, boxes and other collecting equipment will be supplied to forest officers interested in collecting forest insects for the Research Institute. General collections of insects are of great value for museum purposes as well for the records of locality, seasonal occurrence, etc., that they provide. Collect what are apparently "common" species as well as unusual species. Most insects are identifiable only in the adult stage but the classification of larvae is in active progress at the Forest Research Institute. Larvae and immature stages generally are badly needed from all parts of India. Any material that will help to establish the identity of a larva will be valuable.

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'What's the use of their having names", the Gnat said "if they won't answer to them ?"

"No use to them," said Alice, "but it's useful to the people that name them, I suppose."

(Through the Looking Glass).